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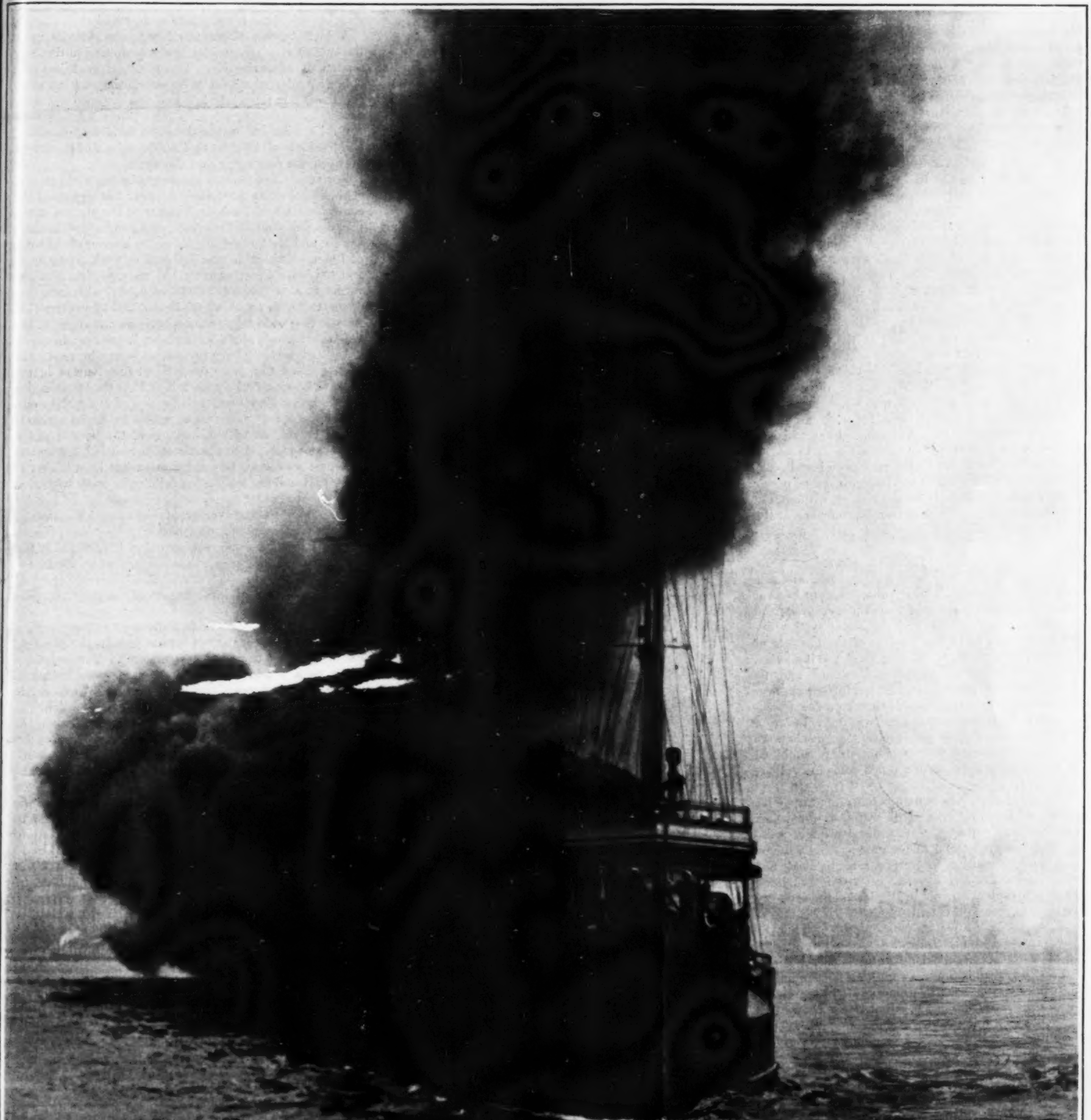


The United States torpedo boat destroyer "Ericsson" in a navy maneuver.

SPREADING A SMOKE CURTAIN.—[See page 393.]

The Thury System of Direct Current Transmission*

Special Conditions That Make Its Adoption Desirable

By William Baum

THE problem of transmitting direct currents in series is not a new one, the well-known Brush and Wood series arc lamp systems being the forerunners of what is to-day called the "Thury system." This constant current scheme has found but a limited application in Europe, having replaced the well-established polyphase constant potential systems in exceptional cases only. The reason for this is to be found in the fact that the direct current system is not a distribution system, but essentially a transmitting scheme possessing, for this particular application, a number of advantages of considerable interest to transmission engineers.

THE PRINCIPLE.

In the usual transmission system one or several generators in parallel feed the line at a potential which is kept constant as far as possible, and the current varies with the load. The Thury system of direct current transmission is a series system in which the generators supplying the power and the motors absorbing the power are all connected in series in a single closed circuit. In this system the voltage varies with the load and it is the current which is kept constant.

In the Thury system the current is constant and exactly the same in the whole of the circuit. The loss due to ohmic resistance in the line and in the machines is, therefore, constant and independent of the load.

The maximum power obtainable in this system is determined on one hand by the strength of the constant current, circuits are in operation with currents from 50 to 450 amperes; on the other hand, for a given current the power is limited by the maximum voltage which is permissible with regard to the insulation from earth. Plants of 100,000 volts and higher have been installed.

The Thury system permits the transmission of power from the generators directly to the motors without the help of any intermediary such as transformers, and at the same time leaves the generators and motors as independent units.

In 1888 when the transmission of power by direct current in series was first employed (Genoa, distance 27 kilometers, 16.8 miles, 12,000 volts, constant current 45 amperes) polyphase current was still unknown from an industrial point of view and the series system appeared at the time to be the solution of the problem of long distance transmission. During the following years, however, three-phase transmission developed and its rapid and successful progress limited the further application of the direct current series system to a few exceptional cases. In these years interest was detracted from the Thury system, due to the fact that engineers were almost entirely occupied with distribution for combined power and lighting purposes for which constant voltage was necessary.

In later years when it became necessary to arrange for transmission of power over great distances for which high voltage was required, certain disadvantages arose in adhering to transmission at high alternating voltage. Due to these difficulties, interest was again awakened in the direct current series system because it avoids all effects due to induction, phase displacement, capacity and leakage to a certain extent.

ADVANTAGES.

(a) General.

One of the chief practical advantages of the direct current series system is the fact that high tension underground cables can be used in which losses in the dielectrics are practically eliminated. Experience shows that it is possible to employ cables of one conductor at high voltages in densely populated centers, across rivers, estuaries, etc.

Another point of interest is the use of the earth as a return circuit. In the above-mentioned papers Highfield refers to experiments which Thury made on the Lausanne-St. Maurice line and reports in detail upon his work on the London line to prove the feasibility of using the earth as a return or as a reserve in case one cable breaks down. These experiments have proven that, owing to its constancy, direct current can be transmitted through the earth with only a small loss. The current density being relatively small (50 to 500 amperes) electrolytic effects upon pipes, etc., are localized to the proximity of the earth terminals.

The Thury system offers several further advantages of which the following should be mentioned. A higher voltage can be used than for alternating current with the same insulation, the great simplicity of the central stations on account of the absence of step up and step down transformers, the absence of complicated switch gear such as circuit breakers and the usual breaking switches, and the impossibility of a great excess of current in case of damage to machines. Where desired, advantage can be taken of the fact that the motors on the Thury system have the property that the torque is independent of the speed.

This system of transmission allows the use of any natural source of power, great or small, which happens to exist in the regions through which the lines run. Individual central stations connected in series are entirely independent of local overloads or lack of demand, whatever the relative importance of these stations may be or whether the distance is great or small from the points of consumption. Their simultaneous running is absolutely independent of the distances covered by the primary circuit, that is, independent of the resistance of the lines.

When the series system is combined with alternating current distributing plants there is no difficulty in linking together several lines fed by alternating stations of different frequency. Series motor-generators thus acting as a link form a valuable, elastic coupling for correcting both the variations of load and the differences of voltage caused by the load on the lines.

The five different three-phase stations of the line belonging to the "Société Générale de Force et Lumière" (Grenoble-Lyon) are coupled and sustained by the Moutiers-Lyon series transmission, of which 28,000 horse-power is used for the general control of the three-phase line (46,000 horse-power) and for feeding the principal center of consumption in the town of Lyon. In this case the advantages gained by this combination of the two systems are important and interesting. It happens daily that two of the principal generating stations of this company's distribution system are unequally loaded with reference to the capacity of the respective three-phase stations which feed them. The Bellegarde station generally has spare power, but that of Grenoble is not able to satisfy the consumers and at times of overload the speed of the turbines decreases slightly. Running in parallel with Bellegarde then becomes practically impossible, but at Lyon, the point of contact of the two lines, at least 100 kilometers (62 miles) from Bellegarde and about the same distance from Grenoble, the series system intervenes and reduces the load of Grenoble, thereby raising the frequency to that of Bellegarde. The latter can then be directly coupled in parallel with Grenoble. Each of the three big stations can thus be proportionately loaded in spite of the disproportion of available power and consumption.

This multi-circuit feature, which makes the constant direct current system especially efficient for inter-connecting a number of stations, systems or networks, can be applied to long distance railroading, as trans-continental lines where the stations feeding the railroad and all available sources of power near the railroad would be inter-connected by a series direct current system, resulting in economy of installation and operation together with a very high degree of reliability.

(b) Absence of Induction Effects.

The absence of phase displacement and effects due to the capacity in the lines is advantageous to the transmission and to the central stations which are no longer exposed to the effects of resonance. At the same time running under small loads is facilitated by the absence of charging current due to the electrostatic capacity of the line at very high tension.

The reduction of corona effect as against alternating current, and the possibility of greatly reducing this effect by using equipotential lines either in case of return by earth or in case of the closed circuit, constitutes still greater advantage over alternating current. The suppression of all indication effects permits the use of underground cables.

(c) Absence of Transformers.

To obtain very high tension alternating current with constant voltage, step up transformers are necessary. Each of these transformers, if it is to be capable ofproducing a tension of say about 100,000 volts, represents a considerable expense. The same high tension can be obtained with the direct current by connecting in series several units at reduced voltage without any machine having to stand more than 5,000 volts between the frame and the winding. This subdivision of the tension has not only the advantage that intermediate transformers are unnecessary, but greater safety in working is effected and also simplicity of the installation.

(d) Transmission by Cable.

The difficulties resulting from an overhead arrangement, due to storms, etc., are eliminated in an underground transmission when such is possible; at the same time the cost of supervision and upkeep is reduced. The value of underground transmission for high tension is recognized especially in crowded centers so that expensive intermediate transformation is avoided.

A high tension alternating current rapidly fatigues the dielectric of the cable, heats it up and ultimately renders it unserviceable. The result is that one can only use underground cables for alternating current when the tension is relatively low and the distance not very great.

Cables with one conductor have been manufactured for tensions of 100,000 to 150,000 volts direct current between the conductor and the earth.

For nearly ten years a single conductor underground cable 9 kilometers (5.6 miles) in length has connected the central station of Vaulx en Vélin with the station of the Cie. des Omnibus et Tramways de Lyon in the Moutiers circuit, and has formed the line to the interior of the town of Lyon. This cable was designed to work normally at 100,000 volts direct current, 150 amperes, but actually works at a tension of 70,000 volts, and although it is connected with an overhead line of 200 kilometers (124 miles) often exposed to atmospheric disturbances, it has not suffered from any accident since it has been in use.

In England the Thury system has been adopted by the Metropolitan Company for general distribution in the West of London (297 square miles). As the transmission had to be underground, the adoption of alternating current suitable for underground cables led to an estimate out of proportion to the economy of the project and it was that which led to the direct current being adopted. The first section of this distribution has been in service since 1911 and the scheme has fulfilled in every way what was expected of it.

The transmission over great distances by means of underground or submarine cables is an economic proposition with high tension direct current at 100,000 to 150,000 volts between the core and the earth, that is, 200,000 to 300,000 between the extreme conductors.

The losses, except those due to ohmic resistance, are negligible.

(e) Earth Return.

The Thury direct current system permits the practical use of the earth as an active conductor. The use of the earth as a conductor presents considerable industrial advantages as it permits a reduction of 75 per cent in the necessary weight of copper for the same tension.

The Federal Government of Switzerland has made tests on the transmission scheme installed between St. Maurice and Lausanne (5,000 horse-power, 2,200 volts, 150 amperes, 56 kilometers or 34.7 miles). One of the two overhead lines was replaced by the earth and the whole town service, traction and light was served during a period of 450 days by a single conductor. No accident caused by lightning or troubles on the earth connections and the numerous telegraph and telephone lines have become known.

The resistance of the two earth terminals, if they are well established, ought not to exceed one ohm. This resistance is only local, the distance separating the two earth terminals being of no influence. The earth can be used in two ways, as a neutral or as an active conductor. As a neutral the earth transmits no current, but only limits the difference of tension between the extreme conductors and the earth to half the total tension. In case of an accident on one of the lines, it permits the other to transmit at least half the energy.

DISADVANTAGES.

(a) Transformation.

Whereas alternating current can be transformed by static transformers, the transformation of direct current requires rotative machines which are more expensive, require greater up-keep and are less efficient. This and the impossibility of subdividing the constant current are the two principal reasons which limit the use of direct current series transmission.

However, with alternating current the transformer must take the full voltage and, therefore, requires elaborate protecting apparatus whereas the machines of the direct current series system only take a part of the total tension. For instance, a motor of 1,000 horse-power in series on a circuit of 300 amperes and 100,000 volts is calculated and insulated only for 3,000 volts, which is the maximum it can absorb, including 15 per cent overload. A motor for an output of 100 horse-power and fed by the same circuit would be calculated for 300 volts.

(b) Insulation from Earth.

All machines on the Thury direct current system form-

* The *General Electric Review.*

ing part of the high tension transmission circuit must be specially insulated from the earth and in such a way that the insulation can withstand the full line voltage without excessive strain. This special insulation is necessary for tensions over 10,000 volts or plus or minus 5,000 volts between the extreme poles of the station and the earth. This insulation considerably increases the cost of the installation of the machines. It is necessary to insulate the bed plates of the machines, and as a precaution for the safety of the men, to insulate the ground around the machines and to avoid having any uninsulated objects around for some distance.

Originally the bed plates were, mounted on a number of porcelain insulators. To prevent any accident, due to the splitting of an insulator, the concrete block underneath the insulators is insulated by arranging a number of insulating blocks underneath it. These insulating blocks are set in a pit which is afterward filled up with an asphalt compound. With alternating current, insulation between the machine frames and the ground is not necessary, but on the other hand, a partition work is indispensable for all sections of the switch gear.

Where the Thury system is used, no general switchboards are required which may be said to reduce the danger to the operators. The necessary instruments are fitted on the machines and are, therefore, insulated by the machine insulation. Only a panel with the controlling instruments is installed at some distance from the machines and if an earth return is not used the panel must be insulated from the ground. This panel may carry a wattmeter, a voltmeter, a standard ammeter, and, if required, a registering voltmeter; t ese instruments being at the same vo tage, can be manipulated when working without any danger. Their winding insulation must be the normal insulation of the corresponding machine.

When the machine has two armatures mounted on the same shaft there must be a specially strong insulation between the shaft and the punchings. This arrangement has been adopted for the Moutiers-Lyon line. The machines are calculated to give a normal tension of 9,130 volts, but are frequently working at 10,000 volts.

(c) *Commutation.*

In the Thury series system the commutators are a weak point as they must be very carefully made and generously proportioned, and this considerably augments the cost of the machines. Great attention must also be paid to the commutators during running, in which respect alternating current machines with slip rings have an advantage. This is undoubtedly the most serious difficulty encountered in the production of satisfactory powerful units at high voltage with low amperage.

The first series machine made in 1890 was designed for a voltage of 1,200 volts per commutator. In 1893, machines were made for a voltage of 3,500 volts per commutator, and later 5,000 volts per commutator. A higher voltage than 5,000 volts has, up to the present time, not been exceeded in practice and this sets a limit to the size of the unit. With 5,000 olts per commutator, twenty commutators are necessary to produce 100,000 volts. With four commutators per unit, which is the case in the La Rosiere station of the Moutiers-Lyon line, five generator units are necessary for the tension of 100,000 volts at a constant current intensity of 150 amperes. The power thus available in this circuit is 15,000 kilowatts, each unit of four commutators giving 3,000 kilowatts. With 300 amperes the power of each unit would be 6,000 kilowatts, and with 600 amperes 12,000 kilowatts, this latter giving a total power of 60,000 kilowatts.

It is evident from the above that the present day limit of 5,000 volts per commutator means that the number of units to give a total high voltage is relatively great. This disadvantage, however, has one good point. In case of breakdown at any part of the plant it will only be necessary to shut down a small section. In a Thury installation erected in Zory in 1891 the generators in this station have been working for eight years at a rate of 18 hours per day at full load without having to change the carbon brushes, and during the 24 years of service not a single commutator has had to be removed. The voltage of these units, however, was not as high as 5,000 olts, but something ike 1,600 volts per commutator.

(d) *Constant Loss in the Mains.*

In the Thury series system the line is fed by a current of constant intensity and the loss in the line is, therefore, independent of the load. The efficiency of such a line is consequently low for small loads and then rises proporti nately with the load. With relatively constant load this is not disadvantageous, but with a varying load the average effici ncy of the transmission is considerably lowered.

When the prime movers used are heat engines or hydraulic machines using large reservoirs, the voltage and copper section of the line is important in order to obtain a suitable daily efficiency. On the other hand, when water power is used without reservoirs the quantity of waste water during hours of small load is of little or no importance. Again, when the transmission line has several central stations in series as is the case in the Moutiers-Lyon line, and one of the stations makes use of the river without any reservoir, the constant loss is then of no importance. If any of the other stations wish to profit by economizing their water or their fuel, they can do so by allowing the station which makes use of the river without any reservoir to work under full flood. Each kilowatt added to the loss in the line is thus completely utilized at the other end without additional loss.

Thus in the series circuit, power can be added to the circuit at any point and this power can be utilized at : ny point of the circuit whatever the distance or the resistance between the two points may be.

(e) *Excessive Voltage Due to Open Circuits.*

As it is dangerous to interrupt a constant direct current, it is necessary to use all means in order to prevent the circuit from being entirely broken, thereby eliminating a dangerous rise of pressure.

GENERATORS AND MOTORS.

A description of the Thury generators and motors has frequently been given in technical literature. According to the *Elektrotechnische Zeitschrift*, 1906, page 1091, the generators of the Moutiers-Lyon plant have cast steel frames with six cast-on poles. The armatures and commutators are fitted on the shaft with bosses. The drum windings consist of form-wound coils laid in slots.

Thury motors are practically of the same design as the generators. The station at Rue d'Alace of the Moutiers-Lyon plant has five series motors each of 720 horse-power, coupled to 500-kilowatt direct current machines giving 600 volts and supplying the tramway circuit in Lyon. These motors are arranged as double machines, each bed plate carrying three bearings and two four-pole frames of cast steel. The poles are screwed on to the frame.

REGULATION.

(a) *Generators.*

In the Thury series system each generator and each motor must have its governor; the generators to maintain the amperage constant on the line and the motors to maintain the speed constant, except in special cases. Two methods of governing the generators are employed, (a) by varying the speed of the generator groups or (b) by varying the position of the brushes should the speed be constant. In the first method one governor alone automatically adjusts the speed of the generator groups according to the tension of the circuit. It works on the turbine nozzles by means of a ratchet and pawl device or is actuated by oil under pressure. The generators are then series wound with fixed brushes and without any regulating device. This method of governing is chosen when hydraulic turbines capable of running at low speeds with half the available flow of water produce the necessary power. To avoid the speed being reduced too far for small loads when the output varies greatly, it suffices to keep only the number of units running which the service actually demands.

Governing by moving the brushes is used when the construction of the turbine requires a constant speed or when the efficiency of the turbines at small load is of importance. In such cases a double control is necessary, one for the speed and one for the current intensity.

Speed governors are those generally used, but they are not required to fulfill the conditions which are demanded of governors controlling alternators; thus, in the series system the control of the speed can be approximative, the division of the load between several units being independent of the speed. The groups of the central stations can run at speeds varying 10 per cent one from another without any inconvenience and the division of the load suffers in no way. These conditions permit the best use of the inertia of flywheels.

This is very important when the inertia of the water in the pressure pipes plays an important part and could produce dangerous hydraulic recoil or surges. The fact that synchronizing is not required renders the governing of turbines or other prime movers with the series system much easier.

The equal distribution of the load between several groups might seem difficult to realize, but the use of powerful governors with a sensibility of 0.2 per cent has made the satisfactory distribution of the load possible. The chief point in the question of regulation, which is in favor of the Thury system, is that all synchronizing troubles are avoided.

(b) *Motors.*

To prevent the speed of the motor varying with the load, a special speed governor is employed. As each motor on the Thury system requires a governor, this is a serious drawback in comparison with the usual alternating synchronous and asynchronous motors. This constitutes a great objection to using the Thury system as a means of distribution.

APPARATUS AND ACCESSORIES.

In the series system the amperage being the same in all parts of the circuit, the necessary apparatus is the same for all the machines whatever their individual power may be. The windings of the different machines bear a great similarity and a uniform section of conductor can be employed. This is also an advantage from a manufacturing point of view.

For each unit the apparatus consists chiefly of a general control switch and an auxiliary switch. The former is mounted on arms fitted to the bed plate of the machine and provided with an ammeter and voltmeter. The object of the latter switch is to isolate any particular unit when cleaning or dismantling is necessary in which case the unit is properly connected to earth. When the rotation of the generators is reversed, they are automatically short circuited through a relay which acts upon the switch. The motors are similarly fitted with safety contrivances. General switchboards are not necessary.

The generators can be started up in a few seconds. In the case of a generator controlled by varying the speed, the attendant opens the turbine valve, the generator being short circuited. Owing to the poles being connected in series their effect is felt after the first two or three revolutions and the amperage rises according to the rate of starting until the normal intensity is reached. By opening the switch, the machine is brought in circuit and this occurs without any sparking.

In the case of a constant speed generator, the machine is brought up to its normal speed, the brushes are moved until the normal current intensity is reached and then the switch is opened. In order to shut down a variable speed generator, the turbine valve is closed and the generator is short circuited as soon as the voltage becomes zero. If the speed is constant, the governor is cut off, the brushes brought to the zero position, and the switch is then closed. The turbine can also be cut off and the switch closed as soon as the turbine stops. Starting-up and shutting-down generators is, therefore, a simple process and no breaking switch is required. There is no trouble as regards synchronizing or adjusting and this is particularly important in case of overload or accidents as synchronizing is in such cases often difficult and the cause of delay just when this delay is very undesirable. One feature of great importance in connection with generators on the Thury system is that automatic circuit breakers become unnecessary. Circuit breakers are not required owing to the fact that a damaged generator does not cause an increase of current but on the contrary the total current is decreased. The precaution taken consists in providing a relay for each governor which automatically shifts the brushes to the zero position in case of accident. The attendants have then only to short circuit and stop the machine. This same relay brings the generator brushes back to zero when the transmission line is accidentally cut or short circuited and prevents any subsequent re-excitation without the intervention of an attendant. A broken line is thus immediately rendered harmless unless doubled by any other line in parallel. In this case the broken line can be automatically cut off without interrupting the general circuit.

COST COMPARISONS.

The cost of a direct-current transmission line is less than that of a line of similar capacity for alternating current, more particularly where underground cables are employed, and forming into any desired frequency and voltage, thus enabling one alternating current station to assist another which may be unable to cope with its load, even though the two stations may not have the same frequency or voltages.

Although the Thury system plants are simple in construction and operation, there are several disadvantageous features; namely, the large number of comparatively small machines necessary, the presence of high tension commutators as against slip-rings for alternating current, the difficult and expensive insulation necessary to insulate the machines from earth, and the rather complicated regulating apparatus.

It is usual for distribution purposes to transform the high tension direct current into alternating current and to do this rotary converters are necessary, as against static transformers in alternating current transmission schemes. Another point in the consideration of the Thury system is that the losses in the line are constant whatever the load may be.

In conclusion, the author desires to express his appreciation to Mr. R. Thury for the valuable assistance rendered to him in the study of this interesting transmission scheme.

Lowering Heat Losses

A NEW idea for lowering heat losses in a long steam line, and which is also claimed to produce greater engine efficiency, has been adopted at a large mine in this country. Large receivers were located near the throttles of the engines, and at the same time the boiler drums were decreased in size, the engineers claiming that the proper place to store steam is as near the engine as possible, as that insures a large supply of dry steam at the throttle immediately available for an engine engaged in hoisting work, where its operation is intermittent and varies in speed. This arrangement enables much smaller pipes to be used, thus reducing the heat losses materially.

Marine Mines*

Their Purpose: How They Are Planted and How Destroyed

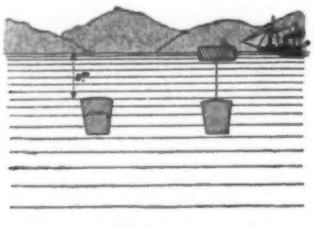
The automobile torpedo is the principal weapon of the submarine, and this has already been described. It is known, however, that these torpedoes are provided with an ingenious and delicate mechanism that enables them to run at a very great speed, often as great as 4,000 feet a minute, and to carry for a distance of five miles or more a charge of very powerful explosives that will be detonated by contact with the object aimed at.

There is another system of submarine appliances which was much discussed during the war between Russia and Japan, and is attracting still more attention in the present war, in which they will undoubtedly play an important part. We refer to mines, sometimes called blockading torpedoes, composed of a metallic receptacle for containing a heavy charge of explosives, which is detonated by a method that will be described later on. These mines have no means for changing their position.

It is generally recognized that there are but two kinds of mines; the drifting mine, which is not anchored and consequently can float at the mercy of currents, and the stationary or fixed mine, which cannot ordinarily be displaced. It is a mistake to think that certain vessels met real free mines in the Gulf of Petchili, after the Russian-Japanese war, and more recently in the North Sea, for in reality they had to deal with stationary mines, that from some cause had broken loose and were drifting around, but they were not free mines, properly so called, for the number of these can be but extremely small.

There is no reason to believe that a system of true, free mines has been made use of in recent wars. They would, nevertheless, be of great service, because they might be employed in such sea areas where the depth would not allow of the use of stationary mines.

The problem of free floating mines is certainly being studied by all naval powers, but it is not believed that a solution has been found. *A priori* the solution can be foreseen in only two ways. First, by a system of bal-



Figs. 2 and 3.—Drifting mines. The first balanced to float below the surface; the second suspended from a float.

ancing the mines by weights so that they will float at a constant depth of about three meters below the surface of the water (Fig. 2), or by suspending the mines from floats, by which means the depth of immersion of the mine could be regulated as desired. This is illustrated in Fig. 3. The method of balancing in equilibrium involves difficulties that seem insurmountable; and while the system of suspending mines from floats is extremely simple, it has the drawback that the float is visible from a distance, thus indicating the presence of the mine, and making it possible for vessels to avoid it.

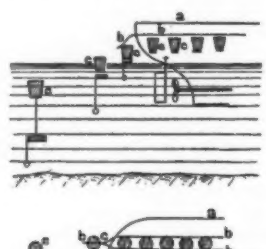
It may be here advisable to explain why it is always endeavored to maintain not only the automobile torpedo, but also mines, whether free or stationary, at a constant depth of about three meters. The reason is that this depth is considered necessary to enable the explosive charge to produce its maximum effect through the confining effect of the weight of a column of water of at least three meters, which produces the same effect as the charge in a gun, which must be confined to develop its explosive effect.

If a mine is exploded against the hull of a vessel at the surface of the water, or at a depth of less than three meters, it would do but comparatively light damage; and this is the reason why vessels drawing less than three meters are generally considered as safe from submarine mines. These mines, as has been stated before, float at a depth of about three meters, and are maintained in equilibrium at that depth by two forces, on the one hand, their own buoyancy, which is about 80 kilogrammes, lifting toward the surface, and the steel cable fixed to a weight resting on the bottom, which resists the buoyancy of the mine.

It will be easily perceived that there would be great difficulty if it was necessary to lower by hand the anchor weight of every mine planted, and to measure the length of each cable. There would be no end to the operations, and one of the great values of the submarine mine is the possibility of being able to plant a large number in a very short time, in order to close a channel, or to blockade an operation of the enemy, which generally must be done under fire. Consequently, a system for automatically planting the mines at the required depths is employed. The vessel engaged in laying a line of mines has only to consider dropping them at equal distances, in a suitable direction; and for this purpose the mine planter has rails on which the mines are suspended, and as the vessel proceeds at a high speed, the mines are thrown off at intervals of a few seconds (Figs. 4 and 5).

Fig. 1.—A mine that has been dredged up, and perforated with bullets.

The depth regulator used by the French navy, and also by a majority of the navies of other countries, was invented by Lieut. Coullant; and roughly, it consists of a winch whereon is wound a length of cable sufficient to hold the mine from 3 to 5 meters from the surface. The



Figs. 4 and 5.—Elevation and plan views of vessel arranged for planting mines.

unwinding of this cable is regulated by a toothed wheel and a pawl, which is controlled by the weight which rests on the bottom.

The zones where mines of this description can be planted are determined by the depth of the water, for it

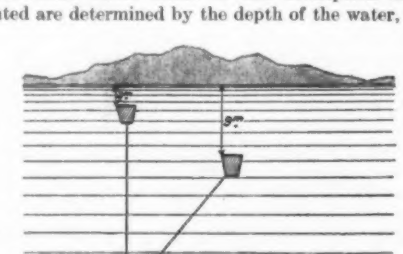


Fig. 6.—Influence of tidal currents on anchored mines.

is evident that if the weight of the cable necessary to secure the mine is greater than the buoyancy of the mine the latter will be drawn down too low. The practical limit of depth would seem to be about 200 meters, but the writer believes that certain countries, especially Germany, have planted mines in depths of 300 meters. Of course, the depths can be increased by increasing the surplus buoyancy of the mine. By consulting the chart of the North Sea, where important events are taking place, it will be seen that an intensive use of submarine mines can be made. In fact, south of a line drawn from the north of Scotland to the Norwegian coast the bottom is uniformly less than 100 meters, excepting on a narrow strip for a length of about 30 miles along the Norwegian coast, where the depth is 300 meters.

The efficiency of mines varies considerably if the waters where they are used are under the influence of tides. In the Mediterranean, for instance, where the level of the sea is almost constant, a mine submerged three meters remains always at that depth, and consequently is always ready to act. In the English Channel, and in the North Sea, besides strong tides, the average difference in level between the high and low tide reaches to an average of 6 or 7 meters. In such cases, in order to prevent the mine from showing at low tide, it is necessary to plant it three meters below the surface at low tide; and, consequently, it will be 9 or 10 meters below the surface at high water, and, therefore, practically harmless. Furthermore, in

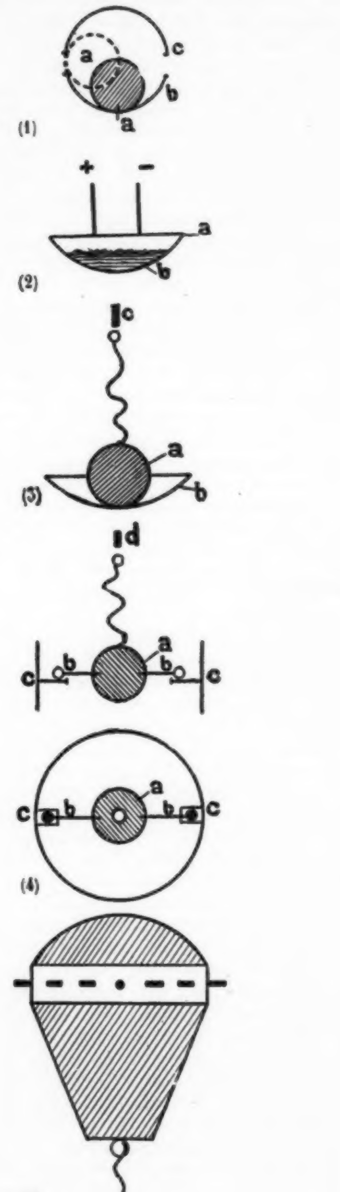


Fig. 7.—Various methods of causing mines to explode when struck by a vessel.

the interval between high and low tide, a mine floating at the end of a cable, sometimes 100 meters long, will oscillate under the force of the tide currents (see Fig. 6), and will be held in equilibrium in a position very much below its normal position, often at a depth of fully 30 meters when a cable of 100 meters is used, and in this condition the mine is entirely harmless. It is obvious how useful would be a system that would insure a constant immersion, whatever the height of the tide might be, but such a system has not yet been invented notwithstanding the many attempts that have been made.

The processes for igniting the charge of explosives contained in the metallic case forming the mine are numerous, and may be divided into two categories, electrical and mechanical. Several methods of electrical ignition are shown in Fig. 7; and in the diagram No. 1 is

* From *La Nature*.

shown one method, where an iron ball, *a*, is free to roll in a cup, *b*. When a vessel strikes the mine it is tilted so that the ball rolls into contact with the upper cup, *c*, thus completing an electric circuit that discharges the mine. Sketch No. 2 shows a similar system, and in this case a cup, *b*, contains a quantity of mercury, which is agitated by the shock of a vessel striking the mine, and

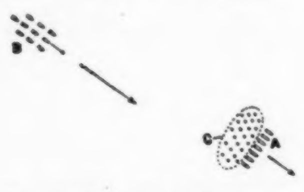


Fig. 8.—Use of mines on the high sea. C, field of mines dropped by a retreating fleet, A, to intercept the pursuing fleet, B.

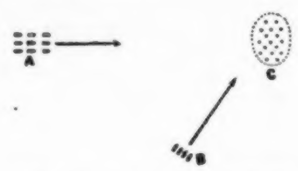


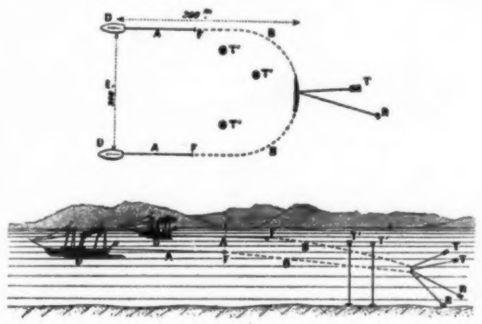
Fig. 9.—A is a fleet of fast torpedo boats going to place mines, C, in the course of a slower fleet of war vessels.

makes a contact between two poles of a battery. A mechanical method of firing a mine is shown at No. 3, where an iron ball, *a*, connected with a firing pin in the fuse, *c*, by a wire, rests in a shallow cup. The shock of contact rolls the ball out of the cup, and in falling it pulls the firing pin. No. 4 shows a similar arrangement, as in this case the ball is provided with two spindles, *bb*, which rest on supports, *cc*. A shock will detach the ball from its supports, and the fuse is fired as in the previous case. In the last case here illustrated, No. 5, the mine is provided with a large number of percussion firing pins arranged at close intervals around its diameter, which will ignite the explosive when struck by a passing ship.

There are numerous uses that can be made of mines in naval operations, and there is no lack of instances showing their efficiency. They can be employed to close the entrance to bays, river estuaries or channels, and several lines can be placed, leaving tortuous channels between them, marked by a secret alignment to enable friendly vessels to pass. They are also used on the high sea, when the depth of the bottom permits, for the purpose of destroying some units of a threatening force, as instanced by the sinking of the Russian warship "Petropavlosk" at Port Arthur, by a mine placed during the night by a Japanese torpedo boat; or for protecting an escaping fleet, as in the case of the German cruisers after their raid on the east coast of England at Scarborough (Figs. 8 and 9).

It remains to consider how these submarine engines may be done away with. The only efficient method appears to consist in dredging them up, and for this peculiar kind of fishing a vessel of small displacment should be employed in order to avoid, as far as possible, a contact with one of the mines. In order to get rid of the mines, or to clear an avenue through which a fleet might pass without danger, two of these small vessels are sent over the ground, sailing on parallel courses, about 200 meters apart, and dragging between them a steel cable about 600 meters long, one end of which is attached to each of the boats. This cable is supported by floats, *f*, about 100 meters behind each vessel, while a weight is attached to the cable at its loop to sink it nearly to the bottom. It has been found that, with this arrangement, if the two boats move at a speed of about 5 knots the loop of the cable will keep submerged to about 10 to 15 meters below the surface. The operation of this arrangement is obvious, for the loop of the cable will catch the cables by which the mines are anchored, and will drag them along. If the mines are of the kind shown in the first four illustrations in Fig. 7, the change in position caused by thus dragging them will cause them to explode at a safe distance.

Dynamometers are placed on the towing vessels in connection with the cable, and these show when mines are caught, and if they do not then explode of themselves the boats are stopped to allow the mines to come to the surface, when they are destroyed by guns, or so perforated



Figs. 10 and 11.—Method of dredging mines. D, D, two light draught boats towing a cable, A, A; F, F, floats supporting cable; B, B, submerged loop of cable; T, torpedo caught by the cable, R being its anchor; T', T', torpedoes about to be caught by the dredge.

that they sink to the bottom, and in this way a passage is cleared.

An infinitely more simple method has been invented by Rear Admiral Ronarch, commanding a brigade of naval fusiliers on the Belgian frontier, by which the mines are freed by a single dredger which cuts the cables by which they are anchored.

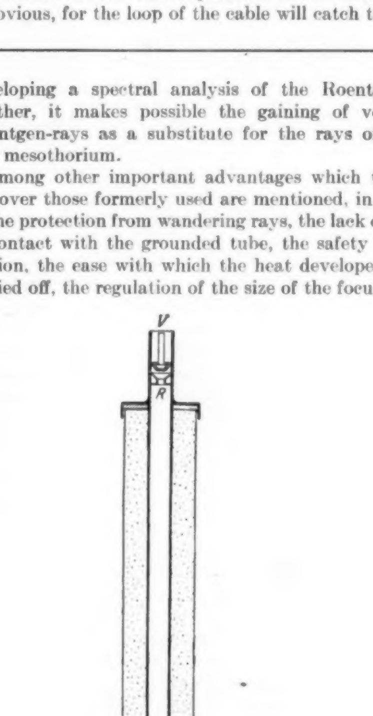
Zehnder's Safety Roentgen-Tube

The dangers, which in spite of all precautions, threaten physicians and patients when the Roentgen-rays are used, arise as a rule from what are called wandering rays. For it has not been found possible in the ordinary glass Roentgen-tubes to cut off the rays passing out in various directions so fully by means of screens that the only exit for the rays is at a specified spot. The problem of complete protection against undesired effects of the Roentgen-rays may, however, have been lately solved by Prof. Dr. L. Zehnder of Zurich. According to the German journal *Prometheus* Dr. Zehnder has constructed a Roentgen-tube of metal which allows the rays necessary for use to pass out only through a small window at a fixed spot. The tube consists, as the diagram shows, of a metal case *M* on which is fixed a high-tension insulator *J*. A metal tube *R* extends through the insulator which, at its upper end, is guarded from the insulator and closed by the valve *V*, while at the lower end it carries the cathode *K*, which is made of magnesium and has a coating of tungsten. This cathode is inserted in such manner in the lower end of the insulator that the cathode rays can pass out only at its lower concave spherical surface. The metal case is used as the anode, and as it is grounded it can be touched without danger. The copper anti-cathode *A* is inserted in the middle of the base *B*, and its working oblique upper surface is covered, according to Schoop's process, with a layer of metal of high atomic weight. Opposite the anti-cathode is placed the air-tight closing window *F*, made of glass or of aluminium, which is permeable by the Roentgen rays. Over against this on the other side of *M* is a secondary case *N*, closed by the sieve *S*, and containing lumps of charcoal *c*. The coal, when heated, as by easily regulated electric heating, or cooled, either yields air to the metal case *M* or absorbs air from it, thus allowing the regulation of the vacuum of the tube. The hollow, cooled anti-cathode can be raised or lowered by suitable screw devices, and its axis can be inclined towards the longitudinal axis of the metal case *M*, and consequently, can be adjusted exactly as needed. The window *F* can be made smaller by various kinds of screens, the pencil of rays passing out, therefore, can be limited as desired; and the pencil of rays can be filtered through aluminium covers, or its passage can be fully checked by impermeable metal covers. The momentary closing of the window in photography presents no difficulties.

It is stated that this new Roentgen-tube was only brought to public attention a short time ago, but even in this brief period it has attracted much attention. Prof. Zehnder believes that the invention can increase a thousand-fold the intensity of Roentgen-tubes of this kind. In addition, it makes possible a very effective concentration of a number of Roentgen-ray pencils at one spot through deflection by means of suitably placed crystal gratings, and offers as well the possibility of developing a spectral analysis of the Roentgen-rays. Further, it makes possible the gaining of very hard Roentgen-rays as a substitute for the rays of radium and mesothorium.

Among other important advantages which this tube has over those formerly used are mentioned, in addition to the protection from wandering rays, the lack of danger in contact with the grounded tube, the safety from explosion, the ease with which the heat developed can be carried off, the regulation of the size of the focus according as use is made of the rays for radiation, illumination, or photographic work, the ease with which the worn out parts can be replaced, the regulation of the vacuum by the secondary case with absorbing charcoal, which case is kept at a determined temperature, and the higher degree of efficiency attained, an efficiency apparently ten-fold above the ordinary.

The first experiments with the new tube were made in January of this year at the cantonal hospital at Zurich. Prof. Zehnder has generously renounced all patent rights for himself and has given the use of the invention free to the world.



Zehnder's Safety Roentgen-Tube.

World's Production of Borax

According to the available statistics concerning the world's production of borates, or boric acid and borax, prior to 1914, it appears that Chile and the United States lead the industry with approximately equal output of these materials, each producing in recent years in round numbers 40,000 to 50,000 metric tons of crude ores, mainly calcium borates. Turkey probably stands third in rank of production, with a reported average production of 14,000 tons of boracite (a borate and chloride of magnesium), quoted as equivalent to 47.6 per cent boric acid, and so comparable to the calcium borates as ores. Peru, Bolivia, and Italy come next, with a production of 2,000 to 3,000 tons each, and possibly also, although no recent record is at hand, Argentina, with a production of about 1,000 tons. India has a small production of 200 to 300 tons, and Germany a still smaller production of about 150 tons from the boracite of the potash salts deposits.

The total world's production of borax may be stated in general terms as 100,000 metric tons of crude materials, a summation which includes various grades ranging from the relatively pure boric acid from the Italian fumaroles to the crude calcium borate ores containing 25 to 40 per cent of anhydrous boric acid.—*Mineral Resources of the United States.*

Cooling Electric Generators

The proper cooling of electric generators is an important matter, and a current of air is generally employed for the purpose. To insure a constant current of air a simple but ingenious device is used by a New York power company. A pilot lamp is provided in circuit with which is a mercury switch. This switch is held in closed position by a jet of air from the air duct blowing against a vane on the switch. Whenever the air pressure drops, the pressure on the vane is correspondingly lowered and the switch is opened by a counter weight. Thus the pilot lamp is extinguished, indicating to the operator at once that there is some trouble with the air supply for that particular generator.

How French Hospital Trains Help to Save the Wounded*

A New and Important Factor in Railroading

By Walter S. Hiatt

As the war goes on the railroad stands out more and more clearly as the inalienable servant of the warring armies. In the beginning it served in its normal capacity as a carrier of troops and supplies, as has already been told in these columns. It remains to be told how France has organized, reorganized, and now perfected, an intricate hospital train service, about which revolves every other service for the wounded. If the lives of more soldiers have not been lost, if the predicted epidemic of disease, say of cholera, has not raged in the trench country and back into France—and I have the word of Dr. Alexis Carrel, of the Rockefeller Auxiliary Hospital at Compiegne for it—it has been due to the careful and rapid transportation of troops all this past summer. Be it understood that the greatest enemy of the wounded soldier is not the bullet or shell, but the infection which sets in as soon as he is wounded, the bullet or shell having carried into the flesh soiled pieces of his clothing. It then becomes a race against time and distance to get the man into a real hospital where his wound can be washed and disinfected. As now organized the staffs of the hospital trains undertake to wash the soldiers' wounds *en route* if necessary.

Beginning before the war with seven hospital trains, kept almost for show, since nobody could foresee the need for hundreds of trains and thousands of specially equipped cars, sufficient to carry a half million wounded a month, there have been slowly prepared in France no less than 250 thoroughly equipped hospital trains, composed of 4,000 cars or one thirteenth the total number of passenger cars used on all the roads of the United States. Each train is composed on an average of 16 cars which form an indivisible unit, carrying from 200 to 400 wounded, according as they sit up or lie down. The total capacity of these 250 trains is about 100,000 wounded. It is estimated that to date, including German wounded, who are treated as well as the French, nearly 1,500,000 men have been carried from the front to the hospitals in France in these trains.

TRAINS LIKE HOSPITAL SHIPS.

Each train is as perfectly organized as a hospital ship. Each has its number, each has red cross emblems painted on every car, each its selected set of officers and nurses who never leave it, each its allowance for supplies, its special equipment and its special duties. While the five different railroad companies continue to carry their accounts separately for commercial freight and passenger traffic, from the point of view of the war department they constitute a single immense company, every car and track of which is at the service of the government. Thus, every morning the seventh direction of the Minister of War receives by telegraph information as to the exact location of each of these trains and issues orders as to where they shall proceed.

The wonderful part about this service is the minimum of cost for operation. Although no less than $160,000,000 is being spent for the wounded this year by the seventh direction, $114,860,000 having already been spent for the first nine months of the year, aside from a sum equally as great spent by private charity, but a comparatively small part of this money has gone into the hospital trains. In large part the money has gone and is going for the supplies needed by the 15,000 physicians at the front or behind the lines, to purchase automobile ambulances, to buy stretchers and medicines, and to keep up the 800,000 beds for the wounded located in public and private hospitals, chateaux, homes, hotels, at the watering places, and, indeed, under almost every roof reared to the sky of sunny France.

The organization controlling these trains is particularly remarkable in that it was born of a necessity which no one but railroad men could understand until the past spring. Literally millions upon millions of men and women, mindful of their own loved ones, have been and are giving of their time and their money to the wounded. But while everybody could visualize the need for stretchers, for additional hospitals, or for motor ambulances for use on the battlefields, or to meet trains at interior railway stations, and to carry the wounded to the hospitals, but few could understand that it was a matter of life and death to fit trains properly for the carrying of the wounded during a brief 10 or 20 hours. So it was only this spring that there came any public realization of the need of organizing the work of the trains. The work that had been done had been carried on by a few railroad men and train surgeons clamoring for money from public or private sources. Finally they were understood and each city of France began to contribute money, then a few Americans contributed money, and now, with the service in good order, funds are available from other quarters.

A NEW FACTOR IN RAILROADING.

The hospital train on a large scale is really a new factor in railroading. Before this war and as early as 1889, M. de la Morandiere, an engineer of the old Western Railway of France, built some model cars which were shown at the French International Exposition. Later a few trains were built in Belgium and Switzerland primarily for the purpose of transporting sick people to the medicinal springs at Lourdes in the south of France. The cars on some of the Swiss trains, which have been used several times this year to transport exchanged French and German wounded home over neutral territory may be compared to some of the tourist or emigrant sleeping cars found west of Chicago. They are corridor cars, with center aisles, and two rows of beds on either side, each bed having running water nearby. One of the curious features is a large mirror provided for each bed.

At the beginning of the war, by August 20, 1914, only the seven hospital trains mentioned above were in use. The half million or so soldiers wounded during August, September, and early October of 1914 were lucky to get to any kind of a train, though in the latter month no less than 600 had been improvised. If they were put on a train, it was composed of some of the 400,000 freight cars hastily filled with straw or of the 35,000 passenger cars where the badly wounded at best had to lie on a cushioned seat. They were shoved therein and moved slowly to some hospital. Often they went for two or three days without water or nourishment or medical treatment. Many died from the jolting, even in the cushioned passenger cars where the jar was still too severe to be borne by the badly wounded.

The conditions existing as late as October 1, 1914, were cited this August in the Chamber of Deputies, during an attack on the hospital service of the army, by a deputy who told how 1,400 wounded were sent into one of the 18 hospital regions of France when in this region there was no room for more. The train surgeons ran from village to village and from hospital to hospital, asking beds for the 1,400 wounded in their care, but were told everywhere that there were no more beds, and finally had to take the train into the neighboring region.

The period of these wandering trains of cars unequipped for carrying the wounded, however, has passed. Scientific study of the conditions has brought about mechanical improvements that are notable, considering the means at hand. One of these improvements, that of a train surgeon, Dr. H. L. Beltzer, will doubtless find world-wide application, because of the possibility of adapting it to any type of railroad car or field automobile.

Through the courtesy of the Minister of War I was lately given an opportunity to see just how this service is organized on which the lives of so many thousands of wounded depend. Before the wounded are finally distributed in the 18 hospital regions of France, they pass through several stages of handling. Beginning at the firing line, which is divided into 16 ambulance divisions for the entire French army and where each division makes its preparations for battle just as much as does an army general, the wounded men are gathered up by company, battalion, and regimental stretcher carriers and taken to a temporary field station, possibly not more than a mile from the trenches.

There they are placed in automobile ambulances according to the nature of their wounds, and directed toward a center for treatment or discharge, known as the hospital of evacuation. This ambulance transportation service is of the greatest importance. The automobiles work in groups of 11, but four of them being used primarily for carrying the wounded. Five are each fitted up for a special surgical use. One serves solely as a sterilization organ, carrying in it antiseptic washes and boilers for heating water. A second is used for radiographic purposes. In it photographs are taken showing the nature of the wounds, and a surgeon may immediately proceed to an operation, if the case is urgent. A third five-ton truck carries medicinal and surgical supplies, with electric searchlights large enough to light a tent or wagon where the surgeons are working. Two other heavy trucks are fitted to carry stretchers and coverings sufficient for 100 wounded. Another truck carries the camp equipment for the nurses, including their cooking utensils, and their supplies of cotton and bandages. This last truck also serves as a supply carrier for provisioning the other ten ambulances. There are no less than 60 men detailed to such a group, including a chief surgeon, 7 assistants, 26 nurses and 17 chauffeurs. Not a few of these Red Cross helpers are Americans, there being a total of 2,000 Americans heping all over France.

These motors discharge their wounded at a point behind the lines, known as the evacuation center. The wounded are here tagged according to the gravity of their condition, a white card for a slight wound, a red for a serious wound, and a blue for a wound of medium gravity. Each wounded man is provided with a paper stating his condition, his company, his name, and the place where he was wounded, and is directed with his effects toward a general distribution railroad center. This intermediate transportation is made either by train, by automobile ambulance or by hospital canal boat, according to circumstances. There are 19 of these great railway distribution centers placed at intervals all over France, the total governed by nine divisional stations, which are in turn governed by the seventh direction of the Minister of War. The 19 distribution centers discharge their wounded in 18 regions, one or more centers to a region.

The wounded arrive at these centers in one of three kinds of trains, permanent rolling hospitals, semi-permanent, or improvised. The permanent trains handle the badly wounded (*grand blessés*) exclusively, the semi-permanent the wounded which must lie down but are not yet considered in a very serious condition, and the improvised trains the wounded which are able to sit upright.

There are special railroad experts detailed at the office of the seventh direction of the Minister of War who keep in touch with every hospital car and train in France, just as a chief train dispatcher does with his freight and passenger trains. Every morning these experts receive reports showing the position of trains unloading in the various regions and indicating the trains needed at the front. When a battle is being prepared at one or more points along the front, they make their preparations just as does the chief surgeon of the army corps involved. These railroad experts, taken from their ordinary duties with some one of the individual companies, know that an attack involving so and so many men means that they will have to provide so and so many trains at the evacuation hospitals to carry away the wounded. Hence there are always reserve trains on hand ready to carry the wounded back to life.

By special permission I was able to visit two of these reserve trains, semi-permanent No. 22 and permanent No. 5. This latter train, in charge of Doctors Jacob and Paillard, had been in service nearly 14 months at the time I visited it. During that period it had carried 4,100 seriously wounded men and had lost but five of them. The train had just been disinfected by having its interior washed with alkaline water and *eau de javel*, and fumigated with sulphur smoke. The trench flies that had followed the train were driven away by a free use of cresyl. All trace of the wounded passengers had been removed and the beds were fresh and sweet as could be desired. The train consisted of 16 cars, several being of the corridor type, with connecting platforms, unlike the old type of French car. There were 256 beds in the eight cars of the train set aside for the wounded, these being placed on either side of the corridor. The hospital crew of the train consisted of 33 men, including a chief surgeon, an assistant surgeon, a provision officer, a sergeant and 28 nurses. Eight of the cars were used for hospital purposes, other than the transport of wounded. One of them, placed in the center of the eight transport cars, was a pharmacy and operating car, a freight car made over at the expense of W. B. Hardy, of Chicago. On its side, near the red cross emblem, was painted the American flag. At the end of the train trailed the car in which lived the 28 nurses. At the head, next the engine, there was a provision car, a short box car fitted up with closets for linen and blankets, and drawers for the storing of wine, sugar, rice, coffee, meats and vegetables. Behind it came a car for the surgeons and a kitchen car containing also space for the storing of dirty linen and cotton, this material having to be burned so infectious disease might not be spread.

A NOTABLE INVENTION FOR SHOCK PREVENTION.

The visit to semi-permanent train No. 22 was of special interest, because there I was shown a new kind of hospital bed that is being adopted on the English and French hospital trains. The big obstacle to carrying the wounded soldiers comfortably has been the lack of the proper kind of beds. There are comparatively few sleeping cars and even these are too heavy for the carrying of large numbers

* *Railway Age Gazette.*

of wounded. There were, however, large numbers of third class passenger cars of the corridor type. They were rather heavy, but the chief obstacle to their use was that they had to be cleared of their old transverse seats and provided instead with iron cots. All this took time, money and workmen; and these three elements were lacking. Besides this, there is a further objection in the case of the very badly wounded to the use of a sleeping car, or to the use of beds at all, because they have to be moved from their stretchers in order to be placed in the car and this not only may mean loss of time, but horrible suffering.

Dr. H. L. Beltzer, the surgeon in charge of train No. 22, last spring devised a frame support for stretchers which is about the simplest thing yet found for the transportation of wounded men either in ambulances or railroad cars. In its simplest form the frame makes it possible to utilize any English or continental passenger car without a single change in the seating arrangement, without injuring the car in any manner, and without installing in it a single bed. When the stretcher is placed in the frame, its handles are fitted into a set of iron rings, each held by a spring, and these springs take up any kind of shock, whether up or down or backward or forward. When the train arrives at its destination, there is no shifting of the wounded man when he is loaded into an ambulance. The stretcher goes with him right to the hospital. In other words, the device means that a man can be carried from the battlefield to a hospital hundreds of miles away without a change of bed.

The device, with certain adaptations, also has the widest application for any kind of freight car. It could also be used in American cars. Dr. Beltzer showed me his operating car and one or two other cars which he had fitted up with a series of slightly different frames provided with strong springs and planted in the very center of the car, each frame supporting six stretchers, three stretchers to a side, the nurses having room to pass the frames on either side of the car. Dr. Beltzer has carried many wounded men in this manner, and during the 10, 20 or 30 hours they have spent in the freight cars on the train, they felt no shock of any description. In some test cases he made at Havre for English hospital officers, he had engines bump the cars severely without disturbing the occupants of the frames.

On the Structure of the Universe—II*

The Ultimate Object of Stellar Astronomy

By H. Spencer Jones, M.A., B.Sc., Chief Assistant, Royal Observatory, Greenwich

Concluded from Scientific American Supplement No. 2084, Page 370, December 11, 1915

Now, if the known spiral nebulæ are distinct from our sidereal system, if they are indeed "island universes" in space, one would expect them to show a uniform distribution relative to the galactic plane. If, on the other hand, they were found to show, as do the planetary and irregular nebulæ, a marked predominance in the galaxy, then the theory of their independence would fall to the ground. As a matter of fact, their distribution is quite different from that of the other two classes.

Instead of being found chiefly in the Milky Way, they appear to avoid it, and largely preponderate in the neighborhood of the galactic poles, although a few are found in the Milky Way. This distribution might be supposed to indicate some connection with our system, but this is not necessarily the case. If they lie right outside it, it is quite conceivable that, in the direction of the Milky Way, none are seen owing to the light which they emit being scattered and cut off by far-extending stars and star clouds of the Milky Way. Further research will be necessary before the question can be regarded as at all settled, but at present the evidence, on the whole, seems in favor of it, and it has the advantage of forming a connecting link between some of our facts and of giving a coherent picture for our minds. It may, perhaps, be mentioned that the very large line-of-sight velocities that have recently been found for some of the spiral nebulæ may possibly indicate independence of our system.

One always associates a spiral with the thought of rotation, and it is undoubted that some at least of the nebulæ are in rotation. Attempts have been made to find whether our system shows any evidence of rotation about an axis perpendicular to the Milky Way. The problem is a very difficult one, involving an accurate knowledge of the precession constant, and of the magnitude and direction of the solar motion, in addition to which it is complicated by the effects of star-streaming.

It is, therefore, not surprising that, up to the present, no concordant results have been obtained beyond the proof that the rotation—if it exists—must be very small in amount. The search for a great central sun—the hub of the universe—about which the whole system is turning is one that appeals strongly to man's imagination, and several attempts have been made to discover such. Madler decided upon Alcyone, the brightest star in the Pleiades, but this supposition is untenable. If such a central sun exists there is little doubt but that it must be situated in the galactic plane, whereas Alcyone lies far outside this plane. Easton, on the other hand, decided upon a center situated in the constellation of Cygnus, a rich galactic region containing many nebulæ. It has been mentioned above that, as a result of the study of the distribution of stars in galactic latitude, it has been concluded that our solar system lies slightly to the north of the galaxy, so that Easton's conclusion cannot be admitted.

A more recent discussion by O. W. Walkey indicates that Canopus may be the sidereal center. Although further evidence is necessary before this can be definitely asserted, yet this supposition appears more reasonable than any previous one. Canopus is the second brightest star in the heavens, its magnitude being 0.86. In general, it is safe to assert that the bright stars are the near ones, but this is certainly not the case with Canopus, whose parallax was investigated by Sir David Gill. Using eighth-magnitude stars as comparison stars, Gill found for it a zero relative parallax, and this careful determination therefore indicates that its parallax is the same as that of the comparison stars—i. e., of the order of a few thousandths of a second of arc. It follows from this that Canopus is probably from ten to one hundred thousand times as luminous as the sun. One feels that such a star, one of the greatest, if not the greatest sun of which we have any knowledge, has a claim to our consideration, as being very suitable for the sidereal center.

The position of our sun relative to the galactic plane can be fixed, as far as its galactic latitude is concerned, with a considerable degree of accuracy from the counts of stars in various regions of galactic latitude. The determination of our lateral displacement relative to the plane is not nearly so easy. Were the Milky Way a band of stars of uniform density the matter would be comparatively simple, for it is obvious that the number of stars in the Milky Way included within a range, say, of 5 degrees of galactic longitude, would reach a maximum for the 5 degrees which included the center of the Milky Way, and it would simply be necessary to determine the direction in which the stars of the Milky Way are the densest. The problem is complicated, however, and the results obtained rendered uncertain by the local irregularities of the Milky Way—the occurrence of regions of exceptionally great star density, and the numerous branches leading off from the main track.

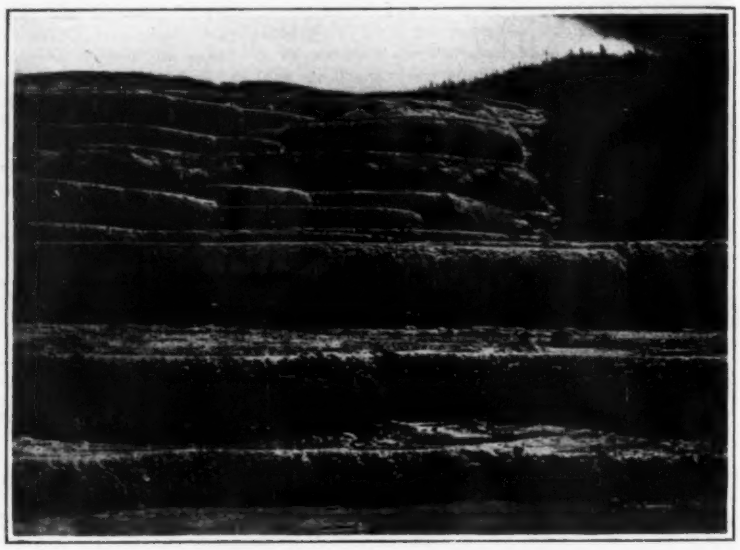
Fairly concordant results have nevertheless been obtained by Walkey, who has discussed the question, using counts of stars down to various limits of magnitude and of various types. He concludes that the sidereal center lies approximately on the 230 degrees galactic meridian. Further investigations will be necessary to confirm this result, but at present it may be taken as a first approximation. From this result, by estimating the relative vertical and lateral displacements of our sun relative to the sidereal center, Walkey concludes that the latter lies on the 230 degrees galactic meridian in about 30 degrees south galactic latitude, which gives a direction passing very close to Canopus, and that its distance from our sun is about four hundred light-years, although much weight cannot be attached to this estimate. In support of the contention that Canopus is the sidereal center, it is further necessary to show that it is situated in the plane of the galaxy, and that its distance, as derived from the distances of the opposite galactic streams, agrees with its known measured distance.

This cannot be done at present, because it is impossible to measure the immense distances concerned with any accuracy. The Milky Way may be at any distance from 1,000 parsecs upward (one parsec being a distance corresponding to a parallax of one second of arc; it is equal to 3.26 light years), and although it is certain that the parallax of Canopus is less than 0.01 second, yet a change in the assigned value by a few thousandths of a second of arc one way or the other will halve or double its distance. But, although the theory cannot, at the present time, be either conclusively proved or disproved, yet some support can be obtained for it. From a statistical study of the measured line-of-sight velocities of stars, the velocity of the sun in space can be deduced, and also the direction of its motion, though this latter can be derived more accurately from a study of the proper motions. This velocity being known in magnitude and direction, any observed line-of-sight velocity can be freed from the effects of solar motion and the absolute velocity of the star in the line-of-sight obtained. When this is done for Canopus, it is found that, within the limits of experimental error, its line-of-sight velocity is zero. It must here be remembered that the observed stellar velocities are purely relative: the deduced solar velocity is a velocity relative to the mean of the stars or to the mass center of the system, and, in fact, different values are obtained from stars of different types. Our whole sidereal universe may itself have a motion of its own through space, just as our own solar system has among the stars of our stellar universe, but such a motion can only be detected by means of observations of bodies lying outside our system. If the view that the spiral nebulæ fulfill this condition be supported, then when the radial velocities of an adequate number of them have been measured, we may be able to find whether our system as a whole has any motion.

Remembering this, it follows that the sidereal center must be at rest relative to the mean of the stars, and the fact that Canopus has no motion in the radial direction, while not proving that it is the sidereal center, is a link in the chain of evidence. If now we assume that it actually does occupy this position, it follows that it can have no velocity in a direction perpendicular to the line-of-sight, and, therefore, its observed annual proper motion of 0.0184 second must be parallactic in origin, being an apparent motion due in reality to the motion of our own sun. The known speed of this motion provides a means of calculating the parallax of Canopus, upon the above assumption, and the resulting value is 0.0067 second, corresponding to a distance of 149 parsecs. This is the order of magnitude of the quantity to which Gill's direct determination led. This distance, being assumed correct, provides a base line from which to measure other distances in our system, and the resulting distance of the galaxy is found to be about 2,000 parsecs, or about 6,500 light-years. We can only say, in reference to this value, that it is of the order of magnitude usually assigned. There, for the time being, we must leave this theory. The evidence, so far as it goes, is concordant, but it must be left to the future, when, perhaps, some new and indirect means of determining accurately these immense distances may be evolved, to establish it firmly or to disprove it. The idea that the center of our system is occupied by an immense sun, many thousands of times larger and more glorious than our own sun, and that round about it are millions of lesser suns of various sizes, together forming the nucleus of an immense spiral nebula, of which the spiral arms coiling around the nucleus appear to us as the Milky Way, and that this to us immense system is but one, and perhaps a comparatively small, island universe among thousands or millions of other island universes in space, is an idea which by its magnificence appeals to the mind of man. Upon what basis of truth this conception is founded I have endeavored as briefly as possible to elucidate in the present article. So brief a discussion of so great a theme is necessarily, both from limitations of space and from present incompleteness of knowledge, very inadequate, and many important and related phenomena, such, for example, as that of star-streaming, or Russell's theory of "giant" and "dwarf" stars, which changes the commonly accepted order of evolution, have not been touched upon at all. Meanwhile, almost daily knowledge is being gained, and new light being thrown upon these problems, and, although in some cases, the new facts seem to find no place ready for them in the theory, and, although in others, they lead to a recasting of many of our ideas, yet progress is continuous, and there can be no doubt that in course of time many of the puzzling facts will find a natural explanation as the theory develops.

* *Science Progress.*

Mount Tarawera and Lake Rotomahana.



Middle section of Pink Terrace.

The Tragedy of Tarawera*

A Volcanic Eruption That Destroyed Many Natural Beauties

PROBABLY the most weird and wonderful region in New Zealand is at Tarawera, the scene of a tragedy which occurred in 1886. To reach Tarawera the tourist is taken in a launch across the hot lake Rotomahana, and the cruise is usually a thrilling experience. The steam-jets ascending from the surrounding cliffs seem like spurts from a huge caldron hidden amid the recesses in the rocks. Boiling water is ejected in great force from numberless jets overflowing into the lake. Doubts concerning the boiling water in the lake were soon settled, for a member of our party, doubting the statement of the guide to that effect, tested its warmth for himself, with disastrous results.

Our attention was called to the former site of the peerless Pink and White Terraces which made this region one of the great marvels of the world. They now lie buried under ninety feet of mold and ashes, due to the eruption of the great volcano Tarawera. The Terraces consisted of two immense terraced slopes, formed by the action of the downward dropping hot water, heavily loaded with silica. Every terrace contained a succession of fairy-like baths and basins, filled with water tinted either bright blue, ivory white, or a faint tinge of bright pink.

The exquisite natural carvings and flutings formed by the dripping water, the beautiful tints of the terraces, the blue of the sky overhead reflected in the lake beneath—all combined to form a picture the like of which does not exist on earth to-day. Sometimes the Terraces, when illuminated by the sunshine, glittered with opal hues, arising from the action of light upon the water rippling downward to the lakes. The marvelous structure was due to the action of a geyser suddenly opening on the hillside. The destruction of the Terraces in 1886 was caused by the eruption of Tarawera. Perhaps no one regretted their loss as deeply as Sophia, the old Tarawera guide, whose native name, "Hingerangi," means "Young Girl in Heaven." She was born at Russell, Bay of Islands, in 1830, her father, Alexander Grey, being a Scotchman; and her mother, Hingerangi, a pure-blooded Maori of the Tohurangi tribe. In her younger days, we are told, she was a pretty girl, and even at the time of the eruption of Tarawera she was a striking-looking woman. Those who heard her relate her thrilling story of the awful catastrophe of June 10th, 1886, were deeply impressed by her striking language and dramatic gestures, as with flashing eyes she described her terrible experience on that night of horror.

"They are gone—quite gone—those lovely Terraces," was her lament as she pointed to the place where the water now flows, hiding for ever from view that lovely work of nature. About a week before the eruption, Sophia had noticed, while taking a party of tourists to Lake Rotomahana, that there was no water in the creek, and the boats were embedded in mud. Presently the water began to come up with a crying sound all along the shores of the lake, and it floated the boats up and up, and went over to the waterfall, rushing back again, leaving the creek dry as before. Sophia described the water as whimpering "hu! hu! hu!" as it swept round the edges of the shore. The tourists were afraid, and suggested going back, but the natives were anxious to finish the excursion, for there were nine visitors at nearly sixteen shillings a head, a sum that they did not wish to lose. The boatmen assured the tourists it was all right, urging them to get into the boat, when the party started on its way.

"We pulled away about a mile and a half," Sophia relates, "when I looked around and saw a small canoe with one man in it come from under a pine. We thought it was someone trying to catch fish, and the men in the boat said, 'Look! There is someone going to catch *kouras*' (a species of freshwater crayfish); but, as we looked, the canoe got larger and shot out into the lake, and from one man the number increased to five. They were all paddling fast, fast, and to our horror they appeared to have dogs' heads on the bodies of men. Then the canoe got larger till it looked like a war canoe, and then we saw thirteen in it, all paddling faster and faster. While we were watching, astonished and terrified—for the boatmen had stopped rowing—the canoe got smaller until only five men were left, and at last there remained but one very big man. The canoe got still smaller, and then, with the last remaining man, disappeared into the waters of the lake."

After seeing this the tourists became very much alarmed, feeling sure that the specter canoe was a warning of some terrible event about to take place, but Sophia exclaimed, "What! you come all this way to see the Pink and White Terraces, and want to go back without visiting them. No, no, it is all right. See, we will go on." She then guided the visitors around the White Terraces, where they had lunch before going on to the Pink Terraces. Here Sophia saw the old Maori chief, Raugihena, telling him of the rising waters, and the apparition of the war canoe with the thirteen men paddling. The old man was sitting at his door with his arms folded, and he asked if she was telling a true story. "Yes," replied Sophia, "everyone in the boat, including the nine tourists, saw it."

"Then," said he, "if that be true, there is going to be a big war, and many chiefs and people will be killed. Alas!" The old chief perished afterward in the eruption, for he went with his family to one of the islands on the lake; and while there the island was overwhelmed, and every living thing destroyed.

Six days after the warning Sophia guided a party of tourists to the Terrace as usual; and, among the sights, they visited a geyser which was sending out flames and smoke—a most unusual occurrence. This was on Thursday, June 9th. The water was very high in the lake; and, on returning to Rotomahana Hotel, Sophia told the proprietor what she had seen. He ignored her warning, telling her that she must prepare to take a party to Rotomahana for a fortnight.

"Well, well," Sophia replied, "never mind." But her warning was verified that very night. To quote her own words: "I finished my work at 11 P. M. and went to bed. But I had only lain down about five minutes when I felt the earthquake coming, heaving up the ground like waves. My old man went out and called to me, 'Sophia! the water is running down the hills.' I asked: 'Is it raining?' and he said, 'No.'

"Then I went out myself and heard it running down the hills. Then I went to my two old aunties, and asked them, 'What is this?' for the earth was shaking and heaving; but they said it was all right, and would soon be over. But I was frightened, and said to the old aunties, 'Come, we will go up to my wharé,' and just then the ground swayed up and down like waves, and the booming commenced like big guns going off and rolling like thunder.

"I was terrified, and went quickly down to get the children, and took them to my wharé, where I found ten or twelve people already. At half-past twelve the noise seemed to get louder, the thundering and booming with explosions, and a continuous vibrating sound like 'hm! hm! hm!' It was as light as day; yes, almost like the sun that is now shining on us. The light came from the crater. Then an appalling crash, and my old man said to me, 'Come and see; the world is going to be burnt!'

"It was a grand and awful sight. Tarawera in flames, rising high into the sky, the red-hot stones and lava pouring down its sides, the beautiful lake glowing in the blaze of light, all bright like noonday, and the surrounding bush nearest the mountain in flames. A great wind, too, came rushing down the Wairoa Valley toward the eruption, and so the splendid forest was blown down and quite destroyed. At half-past one a big black cloud came over Tarawera, settling over it, black as the darkest night; and there we sat in my wharé waiting, as we thought, for the last moment to come.

"We could hear the people come crawling along the little pathway, groping their way up the hill, for they could not see, and were only able to feel their way along. There was not a ray of light, only the blackest darkness, such as I had never seen before or since. At last there were sixty-two people huddled in the wharé. While we were sitting there the red-hot stones and ashes began to fall, and under their weight the roof nearly gave way, so my old man and some of the younger ones got some wood and propped up the roof and walls, though fortunately the wharé was very strong and well built.

"The noise never ceased, and the terrible roaring was continuous. Then came the earthquake, and Rotomahana, another part of the mountain, exploded between half-past two and half-past three. All the people in the wharé were terrified. They wanted to rush out, but I would not let them go, saying, 'No, you shall not go. If you do, you will be killed. You must stay here, where at least we can all die together.'

"All through that awful night many were praying, each in his own way. At eight o'clock it was lighter, and an hour later we went outside, walking on the hot ashes and flint stones. As we went by the Green Lake, we met many who were crying bitterly, for their children or friends had been killed by the falling stones. Young Mr. Bainbridge, an Englishman, was killed by the falling of M'Crae's Hotel. As we reached the Blue Lake, we were met by friends from Rotorua, who came to look for us, and were delighted to find we were safe after this night of awful horror—a night so dreadful it will live in my heart forever."

Poor old Sophia is dead, but the story of her heroic effort to save people on the dread night of the Tarawera eruption is revived again and again for the tourists who visit Te Wairoa.

Leaving Rotorua at a quarter-past eight on the morning of June 15th, 1913, our carriage passed along a winding road, skirted by fern-covered, low hills, and beside the shores of two pretty lakes, popularly known as the Blue and Green Lakes, to Te Wairoa, Sophia's home. It is a beautiful spot, shaded with leafy foliage, but deserted and silent as the grave. Walking along a path

* By Mary Proctor in *Knowledge*.

White Terrace, Lake Rotomahana.

Boiling Water, Lake Rotomahana.

leading to the buried village, we saw the wheels of a wagon half buried in the mud, the ruins of the hotel, and a fowlhouse where two little children sought for shelter and were saved. Finally, we came to Sophia's wharé, within which so many escaped with their lives. Then, continuing on our way down a narrow path leading to a cottage, where we stopped for a few moments.

Inside the cottage were relics of the tragedy, such as a hat whitened with pumice dust, petrified ham, a bottle of preserves, Wedgwood china, a chandelier caked with volcanic dust, and a little child's toy lamb. Three or four little girls, dressed in white, were playing with their dolls outside the cottage; and their merry laughter, sounding through the ideal sylvan glade where the bright sunlight filtered through the leaves of the trees, enlivened the scene, making one wonder at the contrast between this peaceful scene and the tragic events of years ago.

Correspondence

[The editors are not responsible for statements made in the correspondence column. Anonymous communications cannot be considered, but the names of correspondents will be withheld when so desired.]

Snakes and Their Value to the Agriculturist

To the Editor of the SCIENTIFIC AMERICAN SUPPLEMENT:

Mr. R. W. Shufeldt's interesting article, "Snakes and Their Value to the Agriculturist," appearing in your issue of November 27th, is a good word spoken in a much neglected cause. Perhaps, however, I may be permitted to offer a friendly criticism of one or two statements which seem to me somewhat inaccurate.

Mr. Shufeldt estimates that 125 blue racers would produce "upward of 500 snakes of that species before the year was out." This might possibly be granted, if at least fifty of the number were females old enough to average ten young successfully hatched. But when we are told that "each of these snakes would be pretty sure to eat a field-mouse apiece during the course of a day," and thus to destroy 15,000 mice per month, and consequently 90,000 in "the six months of the year," I must beg to say that such figures are enormously above the capacity of the most voracious species with which I have met during four years' personal care and observation of about two hundred living snakes of fifteen or twenty different species. With the blue racer I have had no personal experience; but I am quite familiar with the habits of the black racer, which is at most a closely allied species, if not a mere color-variety of the blue.

Now a newly-hatched racer is never more than 12 inches long and is thinner than a man's little finger. It would probably have to be a full year old before it could eat a field-mouse at all, and even then such a meal would suffice for fully a month. But let us waive the question of the feeding capacity during youth, and give the snake five or six years of life and four feet of length before beginning our estimate. A good-sized adult racer, in common with snakes of other species, will require fully two weeks to digest a field-mouse completely, and the period is even longer in many instances. If, therefore, we make the utmost supposition, that the stomach is never entirely without food during the feeding season, the highest estimate within the limits of possibility would be one adult mouse, or two or three young ones, every ten days. It is probably true that young mice are more frequently eaten than adults; let us suppose a ratio of three to one. This gives us, for a starting-point, an average of six mice per month to each snake.

But, in the next place, snakes do not continue to feed at this rate for anything like six successive months. Their feeding begins about the first of May. The dissection of a normal specimen as early as July will reveal the fact that already the abdominal cavity contains a store of surplus fat nearly or quite sufficient for the next winter's hibernation. My own observations convince me that after the end of August even the hardiest species eat very little for the remainder of the season. Thus, the above average holds for only four months of the year, the number of mice consumed after that being practically negligible.

And now, two more facts must be considered. The first is that the snake is entirely "off his feed" for a couple of weeks at the period of sloughing, which occurs about every six or eight weeks, especially in such active species as the racer. The second is, that all the members of the racer family are quite as partial to a diet of frogs and of smaller snakes as they are to mice. The racer's appetite for copperheads has been more than once observed, and certainly adds to its value to man.

Now, taking our first average as modified by these facts, I can only conclude that if each of Mr. Shufeldt's five hundred racers consumes twelve field-mice of various ages during a single season, he will be doing about all that can be reasonably expected of him. This will bring down the 90,000 mice to 6,000 at a generous estimate—a very considerable reduction.

In the second place, I am inclined to think that Mr. Shufeldt is in error in asserting that the garter snake eats young field-mice. Both the statements of competent authorities and my own experience with these snakes tend to show that they never touch warm-blooded food of any kind whatever. If, however, Mr. Shufeldt has actually observed the contrary, I shall be really grateful to him for the citation of any such instances.

Woodstock College. W. H. McCLELLAN, S. J.

Spreading a Smoke Curtain

An Artifice of Marine Warfare

THE large cover picture illustrates an interesting artifice sometimes resorted to in naval engagements, and which is believed to have been invented by American naval officers, although it is now known and used by the navies of other countries. Most of our torpedo boat destroyers use oil for fuel, and if the combustion of the oil in the boiler furnaces is not perfect a dense smoke results. Advantage is taken of this fact under certain circumstances by sending one or more destroyers to run to windward of the enemies fleet, and as near as possible, with the combustion in their furnaces so adjusted as to produce the densest smoke. This is done, according to circumstances, either by reducing the air supply, or increasing the quantity of oil fed to the fires, the result being exactly what we so often see in a smoking lamp.

Under cover of this smoke curtain the larger fighting vessels of the fleet are able to gain positions of advantage with much less danger of being hit than if they advanced in the open. The same maneuver is also of advantage in case of a retreat, as under cover of the dusky cloud a fleet can easily alter its formation or change its course, and injured ships can be gotten out of the line of danger; and this is exactly what the Germans did in the fight with the British fleet in the North Sea.

Of course the leading boat of the smoke producers is very liable to be hit, although it steams at a speed of thirty knots or more, still, with a number of boats following each other closely the maneuver usually can be successfully carried out. It is needless to say that when on ordinary duty no such conspicuous display is made by the boats, and they can be operated so that their chimneys are practically smokeless.

The Critical Temperature of Mercury

HEATING mercury in a capillary tube of quartz glass, surrounded by a platinum spiral, J. Koenigsberger observed in 1912 that the critical temperature seemed to be about 1,275 deg. Cent. He was himself doubtful, but the tubes exploded about 1,400 deg. Cent. W. C. Menzies, also experimenting with quartz capillaries in a muffle furnace a year later, considered the temperature much too low. Menzies noticed, indeed, that the liquid phase disappeared at 1,275 deg.; but that seemed to be due to the softening and widening of the quartz tube, which was not broken in his experiments. From the relation between the densities of a liquid at different temperatures (Rücker and Thorpe) Menzies calculated a critical temperature of 2,600 deg. On the investigation of Koenigsberger, Julie Bender has recently redetermined the critical temperature of mercury at Freiburg (*Physikal. Zeitschrift*, 1915, page 246). She again took quartz capillaries which she partly filled with mercury; her temperature measurements were made with the aid of thermo-couples. One feels doubtful about the use of thermo-couples in mercury vapor, and also about the use of capillary tubes, for such determinations; but they are not easily avoided. The expansion of the liquid in the tube was watched with the aid of a telescope, and these observations could be continued up to about 1,400 degrees, when the quartz began to soften. The ratio of the volume of the mercury to the tube capacity was varied within large limits. Density determinations of the mercury vapor were also made. In these experiments very small volume ratios (0.06 to 0.13) were used, and the heating was continued until the liquid phase had completely disappeared, which occurred at different temperatures with different charges. In one case liquid mercury could still be distinguished at 1,500 degrees. A charge of 0.10—i. e., 10 per cent of the tube capacity was full of mercury—was completely vaporized at 1,320 degrees; the vapor density should hence be 1.35 at that temperature, and it was found that the density of the mercury vapor rapidly decreased after the temperature exceeded 1,000 deg. Cent. As the orthobaric curves obtained with different charges all converged to a point corresponding to a temperature of about 1,650 degrees, Julie Bender assumes that this is approximately the critical temperature of mercury. There is no mention of tubes having exploded, but an interesting observation is pointed out. Up to about 1,200 degrees or 1,300 degrees the mercury vapor was quite transparent and colorless; then a bluish luminescence was noticed, which increased as the temperature was raised.—*Engineering*.

Strength of Paper

FROM an examination of various papers, prepared with different proportions of rags, sizing and loading, it appears, according to *Zt. angew. Chem.*, that the mechanical properties are improved by increasing the proportion of rags. Resin sizing diminishes the strength, while animal sizing increases it. An increase in the proportion of rags, also sizing of any kind, enables a larger proportion of loading material to be retained by the paper. Loading decreases the strength of all papers, the percentage of loss approximating 2.2 times the percentage of loading material.

Fusible Boiler Plugs

IN the issue of November 27th, on page 352, there was a note stating that there would be almost complete immunity from boiler explosions if plugs of tin of 66.6 per cent purity, and entirely free from zinc were used. On its face this statement is apparently contradictory, and the explanation is that there was a typographical error in the figures, which should have read, 99.9 per cent.

The Diesel Engine*

A Survey of It's Evolution as Applied to Marine Purposes

By C. Kloos, Technical Director of "Werkspoor," Amsterdam

When speaking on this subject it is necessary to distinguish engines for naval from those for mercantile purposes. Naval Diesels are nearly exclusively found in submarines. They are all high speed and compactly built and part of the reliability and durability must be sacrificed to obtain lightness and small bulk. Also the fact that the parts are badly accessible is no objection, because plenty of time is always available for repairs. As the marine Diesel was used for naval purposes first, some of the engines for mercantile purposes have experienced the drawbacks of their resemblance to naval motors. The first marine Diesels of any size were started in Russia and were designed for ships owned by Nobel Brothers in Petrograd.

The fact that marine Diesels were first built in Russia was due to the presence of oil wells at the Caspian Sea, whereas other fuels are very expensive in that vicinity. That cheap oil and expensive coal do not necessarily lead to the early adoption of marine Diesel engines is demonstrated on the Pacific Coast, as the western people thought it best to burn their oil under boilers. There existed in Russia several marine Diesels long before the rest of the world considered their manufacture. The construction was mainly the same as the standard land engines of the M. A. N., with some changes, but in the present-day big Diesel engines for sea-going ships only the valves and valve gear are copied from the original land engines. A few small marine Diesels were turned out in 1910 by Sulzer Brothers of Winterthur and the M. A. N. These were high speed, box frame engines of comparatively low power and did not yield much satisfaction in continued service, nearing too much the style of submarine engines. The 600 brake horse-power land engine exhibited by the Werkspoor Works of Amsterdam at Brussels in 1910 was of a general construction since followed in many big marine motors.

Up to 1910 all Diesel engines were designed with the long trunk piston in which the gudgeon pin was fixed, to which the connecting rod was connected. In the Werkspoor engine for the first time a box-shaped short piston with piston rod, cross-head and guide was introduced, such as are now common practice. In this motor, for the first time in a large motor, were applied the four tie rods round each cylinder, coupling most directly the upward forces due to the pressure on the cylinder heads and the downward forces on the main bearings due to the pressure on the pistons. By these means it became possible to keep the cast iron frame very light and to provide for big apertures, as this box-shaped frame had to carry the weight of the cylinder only, no forces being transmitted through it. This design is adopted in most of the later marine Diesel engines.

After the small marine Diesels of Sulzer & Nurnberg, the six-cylinder engine of the "Vulcanus" came as the first full-powered reversible Diesel. The engine had a capacity of 450 brake horse-power at 180 revolutions, the cylinder was 15.7 inch bore and 31.5 inch stroke. The engine was built at the Werkspoor Works of Amsterdam. In the beginning of her existence trouble was encountered with the air compressors and also through the lack of experience of the engineers. The ship, however, is now in permanent service in India to the full satisfaction of the owners.

In the engine of the "Vulcanus," the crank-shafts and guides are inclosed in a casing; the rear and side walls are made of cast iron and shut off in front by light steel sheets. For the big forces tie rods are again applied, connecting the cylinder casting to the bed plate. The latter is trough shaped to collect the lubricating oil. The lubricating oil is forced to the bearings by a pump. The motion of the cam-shaft is derived from the main shaft by eccentrics and rods that work on a small crank-shaft that carries a pinion. This pinion works on two gear wheels of twice the number of teeth, thus reducing the speed of the cam-shaft to half the engine speed, as is necessary in a four-cycle engine. The cylinder casting carries the cylinder liners and on the top are fixed the cylinder heads. All the bearings for cam-shafts, rocker-shafts, etc., are attached to the cylinder casting. The casting serves also as a water jacket.

The engine is directly reversible, there being two cam-shafts. The hand wheel for the reversing is mounted on a handle case, where all the operations necessary for reversing, starting, regulating and stopping can be controlled. It also carries a telegraph. The valves and levers in the cylinder heads do not differ from ordinary four-cycle land practice.

There is only one fuel pump and one spare pump for the whole engine. The oil is pumped into an accumulator, which stops the pump when full by keeping the suction valve open. The "Vulcanus" was first equipped with an accumulator for this purpose, consisting of two plungers in line. The smaller one worked through a stuffing box in a cylinder containing oil, the larger one in a cylinder with air, directly connected with the air line for in-blast. The pump was automatically cut out by the motion of the plunger and then the latter forced the oil to the cylinders. When near its end position it brought the pump into action again. This arrangement was soon replaced by what is generally called the "floating vessel."

This vessel is placed high in the engine room. The bottom is connected to the delivery of the fuel pump and to the fuel inlet valves on the cylinder and the top is connected to the in-blast air line. This vessel is mounted on a balance with counterweight, in such a manner that it will sink a few inches when full and rise when empty; this motion is transmitted to the suction valve of the fuel pump, which is thereby kept open or left free. But one fuel pump is required for the six cylinders, as the distributors work perfectly with only a difference in pressure before and after the valves in the distributor equal to the pressure of a few feet of oil column, according to the height of the floating vessel above the fuel valves in the cylinder heads. Another advantage is the amount of fuel always ready for starting and in case a pump should get out of order. This floating vessel has given great satisfaction.

The "Vulcanus" held for a full year the place of being the only full-powered sea-going Diesel engine ship afloat, when the "Sembilan," built by Werkspoor, came into service. This ship has a comparatively small engine, 200 brake horse-power, in three cylinders of 15.75 inch bore and 19.68 inch stroke. The engine is reversible. The whole arrangement was built on the style of a much larger engine and experience with the "Vulcanus" influenced the design. Many features that had proved to be good were retained—the floating vessel, the tie-rods, the links for the cam-shaft motion. The Werkspoor patent piston-dismounting device was introduced. The overhauling of the pistons was thereby much facilitated. The piston is dismounted from below, by simply lowering the cylinder extension; no pipes need to be disturbed and the cylinder head can remain in place. Another improvement was the intermediate crank-shaft below, running at half-speed to drive the valve gear. With the "Vulcanus" the links moved with the speed of the engine; on the "Sembilan" they revolved with half that speed; besides there were three links, always in tension, whereas the two links of the "Vulcanus" engines were in tension and compression alternately. The "Sembilan" runs in East Indian waters and her success induced the owners to order five more engines for larger vessels.

In February, 1912, the first marine Diesel engine built by Burmeister & Wain commenced work in the "Selandia." She is a twin-screw vessel with engines of 1000 brake horse-power each, four-cycle. By the courtesy of this concern I give a comparison of the Diesel ship "Siam" with two steamships, "Kina" and "Arabien." The ships belong to the same owners. The "Kina" and "Arabien" are single screw ships 385 feet between perpendiculars, 53 feet beam, 26 feet 10¾ inches draft, deadweight 8720 tons and bunker capacity, coal 770 tons. They were built in 1911 and engined with triple expansion steam engines and are the most economical steamships of the company's fleet. The Diesel engine ship "Siam" is 410 feet between perpendiculars, 55 feet beam, 30 feet 6 inches draft, deadweight 9700 tons and bunker capacity (oil) 1250 tons. The engine room force on each steamer consists of three engineers, two assistant engineers and fourteen firemen, a total of nineteen men. On the "Siam" it consists of four engineers, five assistant engineers and four oilmen, a total of thirteen men.

The steamship "Arabien" bunkered fourteen times while the "Siam" bunkered only three times, and of these one was caused by a mistake in executing orders.

A saving of about 68 per cent in fuel expenses is the practical result obtained with the Diesel engine on this voyage. This includes all consumption for loading and unloading, lighting, heating, etc. The extra saving by smaller crew and bigger cargo carrying capacity is not taken into account. The longer the non-stop voyages, the more economical the Diesel engined ships are, the only condition is that the ship may enter harbors where oil is available.

Following the "Selandia," I now have to put forward the "Eavestone." She was of 4500 tons displacement,

Diesel ship "Siam," second voyage, trip around the world:

Outgoing cargo	9500- 780 or 8720 tons
Cargo between West Coast and Japan	9500-1056 or 8440 tons
Homebound cargo	9500-1215 or 8285 tons
Average cargo for whole voyage, about	8500 tons

Steamship "Arabien," fifth voyage:

Outgoing cargo	8720-1555 or 7165 tons
Cargo between West Coast and Japan	8720-1085 or 7665 tons
Homebound cargo	8720-1120 or 7600 tons
Average cargo for round voyage, about	7500 tons

From the engine logs of these ships the following items are of interest:

	S.S. Arabien.	M.S. Siam.
Duration of voyage	300 days	236 days
Time spent at sea, engines working	183 days	140 days
Distance in miles	45,676	34,819
Number of hours regular running	4,278	3,279
Average speed in knots	10.7	10.6
Aux. engine running, hours, P. and S.	....	5,204
Fuel consumption per mile, pounds	410.8	91.5
Lubricating oil consumption per i.h.p. hour	....	0.03 oz.
Fuel consumption for firing up	66 tons	
Stand-by losses	77.5 tons	
For full steam, no propulsion	16.95 tons	
Regular propulsion	7,600.75 tons	1,357.9 tons
Maneuvering	102.5 tons	18.3 tons
Electric light	149.75 tons	23.4 tons
Heating	49.25 tons	27.5 tons
Winches and pumps	396.25 tons	18.9 tons
Fuel for main engine	7,863.7 tons	1,376.2 tons
Fuel for auxiliaries	670.0 tons	69.8 tons
Total fuel consumption	8,533.7 tons	1,446.0 tons
Economic results for trip around the world:		
1000 tons of cargo carried one mile at a speed of 10.6 knots at fuel consumption of	55.1 lbs.	10.8 lbs.
Price of fuel per ton	\$5.40	\$8.60
1000 tons of cargo carried one mile at a speed of 10.6 knots at fuel expense of	13.5 cts.	4.2 cts.
Total fuel expense for round the world 35,000 mile voyage, which coincides with "Siam's" case of 8500 tons at 10.6 knots	\$40,000	\$12,600

8200 tons deadweight capacity and 9.7 knots speed. One single-acting two-cycle Carels Diesel engine was installed, having four cylinders of 20 inch bore and 36 inch stroke. The power was 800 brake horse-power at 95 revolutions. She made her first long trip across the Atlantic, but on her homeward voyage had considerable trouble. New pistons and cylinder covers had to be sent to her to continue her voyage and arriving home she had to undergo heavy repairs.

Carels of Ghent and Lisences installed the following engines: Two 900 horse-power auxiliaries in the sailing ship "La France," a six-cylinder 1500 horse-power engine for the "Rolandseck," a 2000 horse-power engine for the "Wotan," the engine for the "Fordonian" and the Carels Company themselves built several engines for the British Admiralty.

I believe that the main reason for the absence of repeat orders for these engines lies in the adoption of the two-cycle principle; they must have met with too many difficulties. In the year 1912 many Diesel ships were put in commission. Aside from those mentioned, there are the "Juno" with 1000 brake horse-power Werkspoor engines and the "Emanuel Nobel" with two such engines. These engines have been repeated several times later and so are others of the same style but of different size. They represent the present day Werkspoor marine Diesel.

Some of the particulars may be put forward. Cylinder and cylinder head are cast in one piece. A very thorough cooling is obtained by this design, especially at the hottest parts of the cylinder and head. In the cylinder head are the customary apertures for the valves. The box-shaped piston is water cooled by sea water introduced by special telescopic pipes without glands. After circulating it is led back to the sea by another set of telescoping pipes. The cylinders are supported three by three in a cast-iron cylinder base. The two bases are connected by an intermediate piece. The box frame has been replaced by a set of steel columns, which secure accessibility combined with strength and lightness. Cast-iron frames carry the guides. They are fastened below to the bed plate, but at the top there is no rigid connection to the cylinder base; strips of steel prevent any horizontal motion, but vertical motions are not prevented. At each combustion the internal forces tend to elongate the steel tie-rods. If the cylinder base were fixed to the cast iron columns the strain would go through these columns and bed plate, which parts would then require to be far heavier. Steel diagonals stiffen the engine in the horizontal direction and prevent vibration. Steel splash guards complete this part of the design. The Werkspoor patent piston dismounting device is applied, as also the

* Pacific Marine Review.

floating vessel or fuel accumulator. The main improvement in this type is that the steel columns scheme is worked out more completely than in previous engines.

In 1912 Sulzer Brothers also put a set of engines in the "Monte Penedo." These are two-cycle, single-acting engines with four cylinders 18.5 inch bore and 26.8 inch stroke, running at 160 revolutions. These engines are remarkable for the absence of inlet and exhaust valves. The only valves in the cylinders are the fuel injection and air starting valves. It makes a simple cylinder head but involves complications in the cylinder wall. The exhaust takes place through openings in the cylinder walls forming one half circle, the other half of the periphery is taken by openings for scavenging air. Of these there are two rows, one above the other, and the communication between the air main and the top row of openings can be blocked by a double seated valve. This ship is probably the most successful two-cycle marine motor in service. After some trouble with the pistons (the extension required to shut the exhaust and inlet ports worked loose) the construction was altered and since then the motors have given full satisfaction. It must not be forgotten, however, that these engines were of the very best workmanship and were worked by a carefully selected set of engineers.

The "Arthur von Gwinner" is fitted with two four-cycle Junkers engines. The principle of the Junkers engine has many attractions. The balancing of reciprocating forces, the absence of cylinder heads and stuffing boxes are advantages of great importance, but difficulties have arisen with the cylinders and the cooling of the pistons requires very difficult details. The ship had to repair very often before her working was stopped by the war.

Some data of a very light engine built for a small Netherlands gunboat by Werkspoor of Amsterdam is here given. The power in each propeller is 600 brake horse-power at 300 revolutions; the cylinders are 15.4 inch bore and 19.7 inch stroke. The two engines are inclined toward the center of the ship and form a triangle. The result is an extremely stiff engine, very accessible and as light as the lightest two-cycle motor of this power at these revolutions. There is one cast steel bed plate for the two motors. This bed plate, which is very light, is connected by steel columns to the two lines of six cylinders, which are united in one block by a bolted flange over the full length of the motor. The weight of this twin motor, including fly wheel, up to the thrust bearing is 33 tons.

In May, 1914, the "Arum," with English-built, Polar-type engines made her trials. The engines are of the single-acting, two-cycle type. Each has four cylinders of 16.2 inch bore and 33.9 inch stroke, speed 135 revolutions, rated power 650 brake horse-power each. After performing various short trips, the "Arum" was sent on her first long voyage to the Persian Gulf, which was perfectly successful.

In a motor ship an important question is how to drive deck machinery and engine-room auxiliaries. When money and a good personnel is available, the best system is electricity for everything. Where fuel is expensive, this system is also the most economical in the long run. In first cost it is the dearest and a staff of engineers is required who can tackle a great many novelties at once. To save cost and dispense with novelties the best plan is to have two donkey boilers. Fire them either by coal or oil and drive everything by steam, including the air compressor required to maneuver the main motor. When the ship runs several days continuously and the motor is four-cycle, the waste gases can heat the donkey boiler, giving plenty of steam for steering. The gain is about one ton of oil per day for vessels of 6000 tons. In short runs this system can not be applied. To drive the auxiliaries by compressed air has not proven a success. In tank ships it is a good system to make the main cargo-discharging pump centrifugal and drive it by a Diesel motor. The same motor can drive the air compressor for maneuvering. This system is slightly more expensive in first cost, but, when the ship has to unload often, is cheaper in service than steam pumps.

In the first years the builders of Diesel engines prescribed the use of solar oil, a distillate of petroleum having a specific gravity of not more than 0.88; a flash point of 180-212 deg. Fahr., and a calorific value of at least 18,000 British thermal units. Most of the Diesel engines up to the present day have run on oil of approximately this composition, but gradually other heavier kinds have come in use. The only inconvenience is that the starting of the motor is not always certain, so that some shipowners prefer to use solar oil when maneuvering even if heavier oil is the usual fuel.

Although it was first thought that asphaltum prevents complete combustion and it was feared that it would cause deposits on the exhaust valves and the pistons, extensive tests proved that, when the motor is in good working order, the exhaust is perfectly clean and no trace of deposit is found after prolonged running. It was found possible to burn oil containing a very high percentage of asphaltum without trouble, as the cylinder temperature, at the moment the oil is introduced, is high enough to start combustion and once started, the temperature rises so high that when care is taken to mix the atomized fuel thoroughly with air, practically all kinds of oil can be burned.

For heavier oils it was necessary to construct a special sprayer, which atomizes the oil more effectively, and to heat the oil in tanks and pipes to and from the fuel pump to diminish the viscosity. On the heavier oils the motor can not be started, so it is necessary to change the motor before stopping to solar oil till the pipes and fuel pump are filled.

This is, in main, the history of the Diesel motor as applied to merchant ships at present. It has proved that this engine, if well designed, well made and well attended to, is reliable enough for the longest voyages and is at least four times more economical in fuel, weight for weight, than a coal-fired steamship, or nearly three times more economical than an oil-fired steamship. The short history has also proved, in my opinion, that it is more difficult to make a reliable two-cycle motor, under the normal sea attendance, than a four-cycle.

Probably the two-cycle motor will become cheaper than the four-cycle, although the results thus far have not shown it. The running economy of the latter is greater, especially when the waste gases are passed through a steam donkey boiler. The cost to make a good marine motor is, and will remain probably, about one third higher than to make a good reciprocating engine of like power, but this higher price is partly compensated by the cheaper ship, because the motor takes up less room and weight than the steam engine and the bunkers can be made smaller. This latter saving depends upon the distance between the places where it is economical to fill up bunkers. The large motor ship requires fewer men than the large steamship; the quality of the men must, however, be higher. Difficulties with firemen are eliminated; but the motor, if not very well attended to, is apt to require more repair than the steamship. Balancing these good and bad qualities of motor and steamships, the fuel price in the parts of the world where the ship has to run will generally decide a choice. In special cases, however, the fuel factor will not be the main consideration, as the following qualities of the motor-driven ship are of greater value: That it does not require any warming up of boilers or engines, the motor ship can start at full speed as soon as the oil tanks are filled. That it is possible for a motor ship to bunker at very long intervals, three or four times longer than a steamship. And last, but not least, that motor ships can be made in which the part of the ship where the engines are placed is of the same temperature as the other parts of the ship. In hot climates this quality will go far to turn the balance when the engineers have a say in the decision.

Micro-Weighing*

EMERGING from primitive life man, in observing his surroundings, is gradually led to explore Nature experimentally with a view of controlling her, as far as possible, in his own interest. In doing so his observations proceed in opposite directions. On the one hand he extends his sphere of activity in endeavoring to survey his home, his country, his continent, his planet, his planetary system, and finally the entire universe. This has been called the macroscopic world. On the other hand he attempts to fathom the inter-relation of particles growing smaller and smaller. This is the microscopic world. In his macroscopic observations he soon finds that ordinary, everyday devices are insufficient and that probably every extension of his horizon requires new means of investigation. (Thus man did not thoroughly know his own planet until the means of communication had been improved; the telescope revealed the solar system; the spectroscope, the bolometer, photography, photometry, indicate the existence of other systems.) On the other hand we may also say that it was only by refining and extending his means of research that man was enabled to penetrate the micro-world. In this direction investigation was stimulated chiefly by the evolution of optical devices: the magnifying glass, the microscope, the ultra-microscope, micro-photography, micro-chemistry. In this category—although only remotely related to the rest—we may also place the weighing of minute masses, which may be called micro-weighing. The problem here becomes to sharpen our sensibility concerning variations in mass to as high a degree as possible in order to ascertain whether our deductions and extrapolations from our more elementary and cruder experiments—deductions that most of us erroneously consider, and were taught to consider, as absolute—whether, we repeat, such deductions also hold for minute and infinitesimal changes, or whether, in this case, variations become noticeable that would alter or modify our original theories. It is thus seen that it may not merely be a question of adapting our instruments to the new requirements, but that the result, ultimately, leads to a further adaptation of our theories, and hence of man himself, to nature; for a new theory or conception, once established, influences our life accordingly and brings us into closer harmony with nature.

The evolution of micro-weighing is somewhat different from that of other micro-investigations. With all of the latter the microscope is of primary importance in as much as phenomena are observed directly under the microscope. The weighing of minute masses, i. e., micro-weighing, has not yet been attempted directly under the microscope and, in the writer's opinion, this possibility is quite remote, although it is true that optical means may be resorted to in reading deflections, i. e., only indirectly. This condition of things is caused by the relation of gravity to the other forms of energy, for in weighing even the smallest object which could easily be placed under the microscope, an apparatus would be required which would be entirely too bulky under the microscope. This reflection may seem rather idle, for the instrument for weighing is simply the balance, and in micro-optical observations, for example, the microscope is the medium corresponding to the balance. We may conclude, however, that a comparison of masses (i. e., the determination of weight) under the microscope (possibly without the aid of a balance), precisely like optical phenomena and possibly by means of the latter, cannot be proved off-hand to be impossible. If this should be feasible, however, the microscope—the most sensitive instrument at our disposal—would have become applicable to the determination of masses, just as it is used with other phenomena. This is a mere suggestion which will require much thought and effort before it will be possible to make any definite predictions as to its practicability.

Regarding the gradual development of micro-weighing we may add the following data. The first micro-balance was probably constructed by Warburg and Ihmori in 1886 (i. e., comparatively recently). The beam of this balance consists of thin quartz rods to which razor knife-edges are fastened by means of cement. The deflection produced by the load is read from a mirror and scale without taring with weights. The smallest weight that can be determined with this balance is one one-hundred thousandth of a grain (1×10^{-5}g.). At present the trade supplies small analytical balances having the same sensibility but a much greater capacity up to 10 grains. These balances are used with weights.

The principle of elasticity for the comparison of masses was first applied by Salvioni. Here, then, we meet with the first departure from the devices used in ordinary work. In the spring balance, it is true, elasticity also finds application, but in an entirely different form. Salvioni horizontally clamps at one end a quartz fibre which is straight and not bent in the form of a spiral as in spring balance; he then observes, by means of a mirror, the deflections caused by different loads placed in a tiny pan suspended from the other end of the quartz fibre. The deflections are, within the limit of error and just as in Warburg's balance, proportional to the load and the sensibility is about the same in both balances. In Salvioni's balance the mass to be determined counteracts the elasticity.

A new physical principle is involved in the torsion micro-balance according to Nernst and Riesenfeld. In this device a quartz fiber is cemented to the prongs of a vertical brass fork. To this fiber a thin glass rod is fastened horizontally by means of cement. One end of the glass rod is bent and moves, as a pointer, over a silvered scale; the other end carries a tiny pan. In this balance, we have no swinging on knife-edges, but all parts are rigidly connected and a load causes a torsion of the quartz fiber. The lower limit of the sensibility is five millionths of a grain (5×10^{-6}g), with a maximum load of 2 milligrams.

Another type of beam balance does away with the taring with weights ordinarily used with beam balances. The entire operation of weighing is carried out in a case from which the air can be exhausted. A quantity of air inclosed in a small glass sphere serves as a counterpoise. Now if the air within the case is gradually exhausted the ratio between the loads changes according to the principle of Archimedes as applied to air, i. e., the ratio between the glass sphere and the mass to be determined—provided that the volumes on the two sides are not alike; the latter, of course, is never the case in weighing solids or liquids. A certain definite pressure inside the case will therefore correspond to the zero point. From this pressure the weight may then be calculated. In this case, therefore, a manometer takes the place of a set of weights. In this manner one ten-millionths of a grain (1×10^{-7}g.) may be determined with accuracy.

Recently Riesenfeld and Möller have described a new micro-balance which is a refinement of the Nernst balance. This new balance, will carry a maximum load of five thousandths of a grain (5×10^{-3}g.), and is sensitive to thirty-three billionths of a grain (3.3×10^{-8}g.), and is therefore regarded as the most delicate micro-balance known.

*Translated from *Prometheus* for the SCIENTIFIC AMERICAN SUPPLEMENT.

Percussive Electric Welding*

Process and Machines for Uniting Similar or Dissimilar Metals

By Douglas T. Hamilton†

PERCUSSIVE electric welding, which is one of the latest developments in the electric welding art, was originated by L. W. Chubb of the Westinghouse Electric & Mfg. Co., during the year 1905. While he was experimenting with electrolytic condensers and rectifiers, he noticed that the wires could be connected to the aluminium plate by the condenser spark when the cells were discharged. It was also noticed that copper wires could be attached to aluminium or that two pieces of aluminium could be joined by the condenser spark. The joint thus made, however, was not strong, but after a careful consideration of the results of these early tests, it was decided to try out this method of welding with a greater condenser discharge.

This method of electric welding was first applied to the welding of aluminium, because this metal had given such trouble in soldering, especially when joining small wires. With the substitution of aluminium wire for copper wire, which has taken place in the last few years, the need for a good means of joining aluminium has become urgent, and the percussive electric method was developed primarily for this purpose after a thorough investigation of the methods available. In addition to the welding of wire, several other special applications have been successfully made, so that a general review of some of the more important points should be of interest. Percussive electric welding differs from the resistance method chiefly in the nature of the current used. For resistance electric welding alternating current is used, whereas for percussive welding direct current is employed. It is possible to weld any two metals, whether alike or different, of high or low melting points or of an unequal thermal conductivity. With aluminium, the oxide which covers the surface of the pieces being welded prevents the metals from flowing together after the ends have been melted in the usual way. Large wires and rods of aluminium can be welded by melting the metal under the oxide film and then suddenly pushing the ends of the pieces together, breaking the oxide film and allowing the clean metal to flow together, but on small wire this practice is not feasible.

DEVELOPMENT OF PERCUSSIVE ELECTRIC WELDING APPARATUS.

Following up the experiments made in 1905, Mr. Chubb designed a condenser giving a discharge on a larger scale, and employing the same principle of simultaneous condenser discharge and percussive engagement that had been used in the original experiments. During the test and development of the welding apparatus, however, it was found that the best results depended upon several variables, such as the condenser capacity, the velocity and force of impact, the voltage and the resistance and induction in the circuit. The first apparatus consisted of two hinged arms with wire grips in their ends. Wires placed in the grips were connected to the terminals of a charged electrolytic condenser. Upon being released, these arms were drawn together, and at the instant of contact of the wires the explosive condenser discharged and the force of impact welded the ends together. This apparatus was not very satisfactory, as it did not allow of a separate study of the effect of the variations in velocity, momentum, kinetic energy, etc. A second apparatus similar in construction to a pile driver on a small scale was then built. This was provided with one stationary and one movable wire grip or chuck. In this apparatus the "forge effect" and velocity could be varied independently by a separate adjustment of the length of drop and mass of the moving parts. Other welding tools have been designed in which springs have been used to shoot the wire holders together horizontally, but this type of device has not been as satisfactory as the "drop-hammer" type.

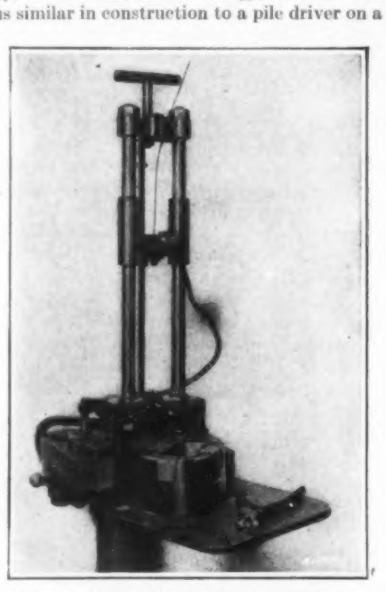


Fig. 1.—Portable welding apparatus.

CONSTRUCTION OF PERCUSSIVE ELECTRIC WELDING APPARATUS.

A percussive electric welding device of the portable type is shown in Figs. 1 and 2. Fig. 1 shows this device set up for welding a copper lead wire to a coil of aluminium wire, and Fig. 2 shows plan and sectional elevations of the device. Referring to Fig. 2, it will be seen that this machine has a base *A* carrying two parallel uprights *B*, which are held together at the top by stationary head *C*. Sliding on these guides *B* is a carriage or head *D* which carries a clamping chuck for holding one of the pieces of wire to be welded.

In order to support carriage *D* in a raised position, adjustable trip *E* held on the rod *F* is provided. Trip *E* contacts with trip *G*, held in the sliding head *D*, and is insulated from it. Rod *F* is so located in its bearings that it can be rotated to bring trips *E* and *G* into alignment with each other. Both trips *E* and *G* are beveled, enabling carriage *D* to be raised, but not lowered until trip *E* is released by a slight rotative movement of the rod *F*, which is again returned to its operative position by means of spring *H*. The wires *I* and *J* to be welded are held in chucks *K* and *L*. Clamping chuck *L* has the general form of a spool or flanged cylinder, and is split longitudinally into two parts which are grooved to receive one of the wires to be welded. The chuck is mounted in a slot in the base of the machine and is held in position and also caused to grip the wire by a thumb-nut. The clamping chuck *K* is similar to *L* and is held in the same manner. The other wire *I* to be welded is conducted down through the top cap of the machine as illustrated, passing through an insulating bushing.

The electrical energy is supplied from a generator *M* or any source of direct current which charges the electrolytic condenser *N*. There is a high resistance *T* in the circuit, and the condenser charge can be varied by resisters *T* and *U*. In operation, the pieces of wire *I* and *J* to be welded are secured in the chucks *K* and *L* so as to project out from the chuck for a short distance. The carriage *D* is then raised to the desired height, which is determined by the setting of the trip *E*. The position of trip *E* is governed by the diameter and composition of the wire to be welded. After the wire has been clamped in position and trip *E* properly set, switch *O* is opened to permit generator *M* to charge condenser *N*. Trip *E* is then released, allowing the carriage to drop and carry the end of the wire *I* into percussive engagement with the end of wire *J*. At the instant of contact, the condenser *N* is discharged, and the energy thus concentrated at the point of contact is sufficiently great to produce a perfect weld between the wires. The weld is then complete, and after being removed from the machine the wire will be found to have the same strength at the joint as anywhere else.

A percussive electric welding machine embodying the general principles just described, but of slightly different

* From *Machinery*. Illustrations Figs. 1, 3, 5, 6, 7 and 8 used through courtesy of *The Electric Journal*.
† Associate editor of *Machinery*.

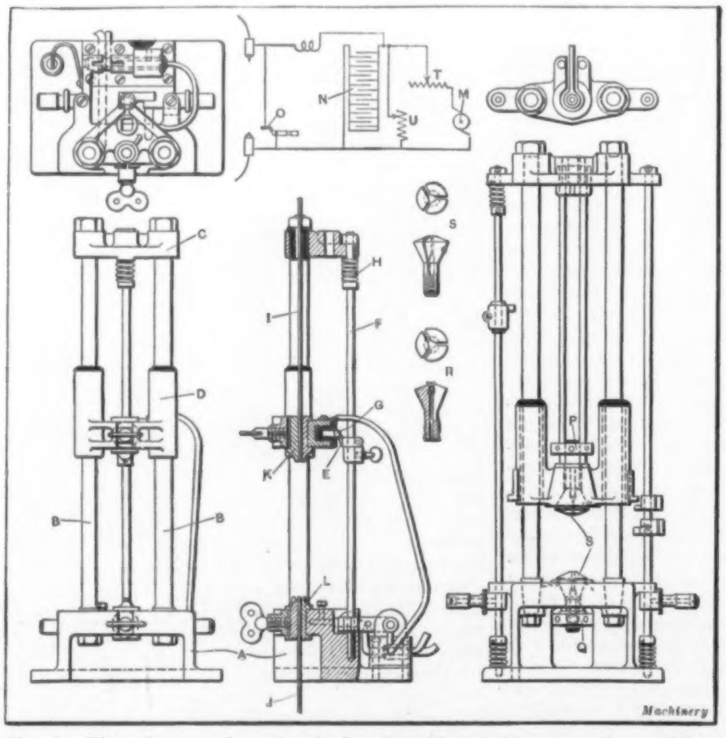


Fig. 2.—Plan, front and sectional elevation of portable percussive welding machine and connections. Two types of machines are shown.

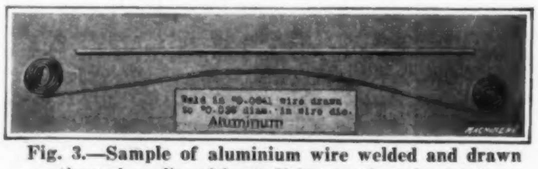


Fig. 3.—Sample of aluminium wire welded and drawn through a die without disintegrating the joint.

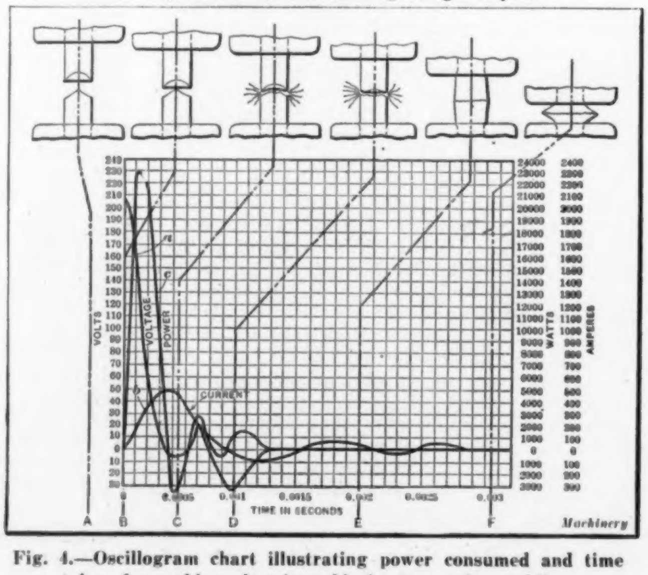


Fig. 4.—Oscillogram chart illustrating power consumed and time taken for making electric welds by percussive welding.

Fig. 5.—Microphotograph of copper and aluminium wire electrically welded, showing intermingling of metals.

Fig. 6.—Microphotograph of a copper-aluminium weld. This shows a magnification of 850 times.

construction, is shown to the right of Fig. 2. In this machine the tripping mechanism is guided by two rods instead of one, and it is also provided with a different type of work-holding chuck, which is shaped similarly to that used on a screw machine and is also split to allow for expansion and contraction. The chuck body is tapered to fit into a correspondingly shaped hole in the base and sliding head of the machine, and is tightened on the work by means of nuts *P* and *Q*. The jaws of these chucks may be threaded as shown at *R* to adapt them to receive small screws if desired. By supporting a small screw in this manner in the chuck and holding a section of platinum wire in the upper chuck, the screw may be easily provided with a platinum tip. Each of the chucks has a pin projection which engages a notch in the holder for the purpose of preventing the chuck from rotating when the nut is being tightened.

DESCRIPTION OF PERCUSSIVE ELECTRIC WELDING PROCESS.

The action that takes place when the wires are percussively engaged covers such a short period of time that it is practically impossible to see it with the naked eye. The only possible way of analyzing the action is to consider it from a theoretical standpoint. From careful observation of a large number of welds and the study of oscillogram records, the theoretical action that takes place between the engaging terminals of the rods to be welded has been graphically set forth as shown in Fig. 4. At *A* the wires to be joined are shown close together as they appear when approaching each other. It will be noticed here that the ends of the wire have been provided with chisel-shaped edges, arranged at right angles to each other. This is done so that the first engagement between the two wires is at a small point. These chisel-shaped edges require no particular care in making, and in fact the thin edge usually produced when wires or rods are cut off with an ordinary pair of pliers or shearing device is satisfactory.

At the instant of contact *B*, the voltage of the circuit falls away as shown by the curve *a*. The current and power, on the other hand, increase rapidly as indicated by curves *b* and *c*. In this particular case, the voltage drops from approximately 207 volts to 160 volts in 0.0001 second and reaches zero at the end of 0.00035 second. The power expended in the circuit rises from zero to 23,000 watts in 0.0001 second, and then almost as suddenly decreases, crossing the zero line with the voltage. The weld in this case is completed electrically, that is, so far as a perfect junction of the two metals is concerned, in 0.0012 second, although the upsetting action still continues to forge the metals together until the upper chuck is brought to rest. Although 23 kilowatts is being dissipated between the ends of the wire at a certain instant, the total energy used at the weld is only 0.00000123 kilowatt hour, or enough to light an ordinary 50-watt 16 candle-power lamp for 0.09 second. The cost of this amount of energy at 10 cents per kilowatt hour would be twelve millionths of a cent. Referring to Fig. 4, it will be noticed that the watt curve *c* is oscillatory and that the negative value would indicate a return of stored energy. Such an action would be impossible from a metallic arc, but can be explained by the fact that the voltage was measured above and below instead of between the wire chucks, so that the storage and return of energy is from the magnetic flux produced in the steel chuck set up by the current of 500 amperes flowing through them.

The time between the first contact and the finished weld is of such short duration that the exact action cannot be recorded, but is supposed to be about as shown in Fig. 4. At *A* the wires are approaching each other at a velocity of about 65 to 200 centimeters per second (25.59 to 78.74 inches). At *B* the first contact is made, at which time the current begins to build up and heat the small section of metal carrying the current. At *C* the ends of the wire have separated, not by any appreciable retarding or reversing of the motion of the upper wire, but by the melting and vaporizing of the metal which first came into contact. At *D* the wire chucks are closer together, but the arc is still burning between the wires. At *E* the second contact has been made, the arc extinguished and the upsetting of the metal has begun. At *F* the complete weld is shown after the upper chuck has come to rest and the upsetting is completed.

The generation of heat is so localized, so sudden, and so intense that there is no time for unequal heat conduction through the shanks of the wire, and the ends wil be melted and even vaporized whether the melting point of the metal is high or low. For this reason various metals and alloys can be welded together independently of their electrical resistance, melting point or heat conductance. All the combinations of metals or alloys that have been tried will weld together, but the joints will not be permanent with such combinations as aluminium and tin or lead and iron.

INTERESTING PHENOMENA IN PERCUSSIVE ELECTRIC WELDING OF METALS.

Although the action of percussive welding is complex, as indicated by the chart, Fig. 4, it is not necessary to construct the welding apparatus or to adjust its parts with more than an ordinary degree of accuracy. Furthermore, it is not necessary to be very careful about determining the capacity of the condenser, the voltage of the charging circuit, or the inductance of the welding circuit. As an example, perfect welds have been made on the first trial between such metals as tin and platinum, platinum and nickel, and copper and aluminium, without special precautions, calculations or adjustments. While the machine is relatively light, a sufficient compression is obtained to forge the terminals of the metals to be welded, and by the use of a condenser of suitable design and capacity a sufficiently intense heat is supplied for a fraction of a second to melt the engaging surfaces and weld such metals as platinum and tin without injury to either metal.

It is believed that such a tremendous amount of energy relative to the size of the conductors not only fuses the engaging surfaces, but vaporizes them, producing a small explosion and actually separating the solid portion of the wires for an instant as shown at *C* in Fig. 4. At this stage of the welding action the terminals of the wire being welded are surrounded by a metal vapor. That this is true is abundantly proved by deposits of metal particles found on the chucks of the welding machine after a number of welding operations have been performed. It is believed that metal vapor surrounds the terminals before they are brought into permanent engagement, and that this is one of the reasons why successful joints have been secured between such unlike metals as aluminium

Fig. 7.—Microphotograph of a copper-silver joint, showing sharp line of demarcation. Magnified 1,000 times.

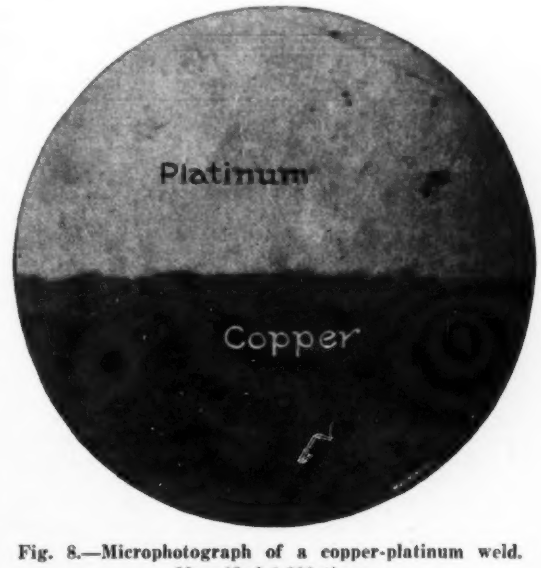


Fig. 8.—Microphotograph of a copper-platinum weld. Magnified 1,000 times.

and copper and between two aluminium conductors, the surfaces of which become oxidized with extreme rapidity when exposed to the air under ordinary welding conditions. It is thought that the small explosion previously referred to actually blows out a certain portion of the terminals in the form of vapor and consumes such a short time that the mechanical energy produced by the dropping of the chucks is still effective in welding the "wetted" terminals. The terminals are not permitted to cool after the explosion and previous to their percussive engagement because the current in the welding circuit, as indicated by the curve *b*, does not die out immediately, but continues to oscillate for several thousandths of a second.

NATURE OF THE WORK PRODUCED BY PERCUSSION WELDING.

It has been found that on account of the intense heat that can be concentrated at the desired point for a short period of time the electric percussive method is particularly effective in making a satisfactory joint. The effect of the concentration of energy referred to on an aluminium wire is to vaporize a small quantity of the aluminium on the engaging surfaces, thereby blowing out laterally in all directions the vaporized material, and carrying off, or at least breaking up, the oxide film which has hitherto prevented the welding of aluminium successfully. In the welding of copper to aluminium by the percussive method it would be expected that the joint would be unsatisfactory, owing to the fact that certain combinations of these metals form a brittle alloy. This, however, is not the case, as welds between these two metals are so ductile that they may be worked in a die, forged or rolled into thin foil. Any alloy that is formed at the junction of the aluminium and copper wires must range from 100 per cent copper on one side to 100 per cent aluminium on the other, but possibly the brittle combinations are so thin that the joint as a whole is flexible and ductile. The possibility of making satisfactory joints between aluminium and copper is of great commercial importance, as copper feed wires which solder easily can be welded to aluminium coils. It was thought at first that a diffusion of the two metals in service would result in a brittle joint, but tests show that after four years the joint is apparently as strong and ductile as when first made. Similar ductility has been noted in almost every combination of metals when first welded, but diffusion, disintegration and loss of ductility eventually result in such welds as silver to tin or aluminium to tin; the welds are effected by what is known in the trade as "tin disease" or "tin-pest"—a disintegration of the molecules.

Metals which are either hardened or softened with heat and sudden cooling can be welded together without appreciable change in the physical properties of the material. Tempered spring steel wire welded and reduced to uniform diameter and tested has shown equal or greater strength at or near the weld without any noticeable change in temper. Metals such as hard drawn copper, silver, aluminium, etc., can be welded without causing any local annealing, and these metals, as well as soft steel, can be welded together without detrimental local hardening. In welding unlike metals by the ordinary method of electric welding a brittle alloy is sometimes formed between the joints of the metal. In percussion welding this is not the case, as the energy and heat are so concentrated, and continue for such a short interval, that there is no appreciable flowing of one metal into the other, the line of demarkation being very sharp, even when the welded pieces are rolled out into a thin sheet or foil. If a film of alloy is produced at the joint, the film is so thin that it is flexible. This is true of various combinations of metals, as will be described later.

EXPLANATION OF SUPPOSED LACK OF CHANGE IN MOLECULAR STRUCTURE IN PARTS ELECTRO-PERCUSSIVELY WELDED.

Several explanations are given for the mechanical properties of various metals before and after welding; some of these are: First, such a sudden heating and cooling may not allow change in molecular structure; second, with hard steel, the heated metal at the weld is so suddenly cooled by conduction of heat into the adjacent cold metal that it is again hardened; third, with hard copper, silver, aluminium, etc., the heating and sudden cooling would ordinarily soften the metal, but the cold upsetting of the blow in welding possibly hardens it again; fourth, the metal is subjected to the sudden heating and cooling so that it may be hardened or annealed (depending upon the characteristics of the material welded), but the amount of material affected may be too small to be detected.

As an example, in welding No. 18 (0.043 inch diameter) hard drawn aluminium wire, 0.00123 watt hour or 1.06 small calories are dissipated at the weld. Assuming that none of the energy is lost in noise, radiation or metallic vapor and that one half of the total is propagated in a heat wave in each direction along the wire, it can be shown mathematically that an annealing temperature will not be reached more than 0.05 millimeter (0.002 inch) from the weld. The total amount of metal softened would be a disk 0.1 millimeter (0.0039 inch) long and 1.02 millimeter (0.0403 inch) in diameter. A soft insertion of such proportions could hardly be detected.

In welds between some metals diffusion takes place, but in any of the useful combinations the change is too slight to affect the ductility of the weld. The welds, as a rule, show only a sharp dividing line between the metals, but there is often an intermingling of the two at or near the center for a short distance. Figs. 5 and 6 show a new weld and a three-year old weld between aluminium and copper. The microphotographs, which are enlarged 850 times, were taken at the irregular point in the weld; elsewhere the line of division is sharp and rather straight. In addition to the small irregularity of the dividing line, some spots of bright material, possibly aluminium-copper alloy, are present at this point, but do not appear at other points in the weld. Both of these welds are so malleable that they are capable of being rolled into thin foil. Wire having such welds was used in actual service at a temperature over 100 deg. Cent. (212 deg. Fahr.) carrying a heavy direct current, and failed to show sufficient diffusion to affect its mechanical properties. The heating current was maintained for weeks and tests were made with the current flowing in both directions. At higher temperatures (red heat) there was a rapid diffusion of the metals, and in a few minutes the metals were diffused for a distance of two or three inches. A percussive electric weld offers a very convenient specimen for the study of the diffusion of different metals at different temperatures and under various conditions. The microphotographs, Figs. 7 and 8, show copper-silver and copper-platinum welds respectively. Both of these welds show a sharp dividing line when enlarged to 1000 diameters. The weld, Fig. 8, is three years old.

It has been found that the electrical resistance of two wires welded together is not appreciably increased by the small film of high resistance alloy at the joint formed in welding. Tests on 85 alternate pieces of aluminium and copper wire joined with 84 welds, making a total length of 23.5 centimeters (9.254 inches) showed an increase of 0.56 per cent in resistance in three years. This test was made to determine whether or not diffusion at the joints would occur. The increase is small and may be due to a change in the joints, or error in observation or oxidation. This sample was recently rolled and showed no change in malleability.

METALS THAT CAN BE ELECTRO-PERCUSSIVELY WELDED.

Thus far, no difficulty has been experienced in welding together any metal or alloys of metals, nor in fact, any combination of metals or alloys. The following are a few of the combinations that have been welded: Tin to aluminium, copper and platinum; lead to tin; tin to platinum; tin to copper; nickel to platinum; steel of various alloys and carbon contents. The chief advantage of the electro-percussive method of welding at present is in the uniting of copper and aluminium, since it is almost impossible to make this weld with the other well known methods, and when made by the resistance method the joints are as brittle as glass. Another interesting feature of the joint made in wires of different materials by percussion welding is the fact that the metal is just as ductile at the weld as it is any other place along the surface.

EXAMPLES OF ELECTRO-PERCUSSIVE WELDING.

While the development of this method of electric welding was brought about primarily to secure successful joints between aluminium and copper wires, it is evident that it possesses wide application. Metals varying widely in characteristics, such as platinum and tin, may easily be welded, from which it follows that almost any metal can be joined where the joint is within the capacity of the machine. The apparatus up to this time has only been made for welding wires 0.072 inch in diameter and smaller, but there is no reason why, with a larger machine and suitable apparatus, wires much larger than this could not be welded as well as other classes of work. Sufficient experimenting has been done to show that the welding of wires to plates or blocks can be successfully accomplished. For example a piece of 1/32 inch copper wire has been electrically butt-welded to a piece of copper 3/16 inch thick; and a piece of 1/32 inch copper wire has been butt-welded to a piece of 1/32 inch brass. In the ordinary method of electric welding, it would be practically impossible to join two pieces for the simple reason that the area of one is so much greater than the other that the wire would fuse and melt away before any perfect junction could be secured. By means of percussive welding, this operation is comparatively simple and a joint is made that is as homogeneous and strong as the metal itself.

In order to show the ductility of metals when percussively welded, two pieces of aluminium wire were joined as shown in Fig. 3. This piece of aluminium wire, which was 0.0641 inch in diameter after welding, was then drawn down to 0.036 inch in diameter through a wire die. The point at which the weld was made could not be determined even under a microscope, which showed that there was no physical change in the wire due to welding and that as far as ductility was concerned the metal was just as ductile at the weld as it was any other place along the section.

There are also many uses of the electro-percussive method, especially in the jewelry trade, where it can be employed for joining platinum without showing any solder line; welding sterling tips to table forks without annealing; welding pins to badges; and many other similar applications. The attaching of contact points of platinum, tungsten, silver, etc., for various electrical purposes is also readily accomplished.

The Conditions of Industrial Accidents

THE enactment of laws in various States on workmen's compensation for injuries has aroused increased interest in the statistics and physical and psychic conditons of industrial accidents. The total number of these accidents is almost appalling. The lowest estimate places the fatal accidents to adult workers in the United States at 35,000 a year, with an additional 1,250,000 non-fatal accidents. The Massachusetts Industrial Accident Board, on the other hand, placed the number of workers killed by accident yearly at 75,000, which apparently includes not only adults, but also workers of all ages, while the number of injured of the same classes was placed by this Massachusetts authority at 3,000,000 or over. An earthquake in a foreign country that kills half this number of persons and maims one-fiftieth of those injured in our United States industries is spoken of as catastrophic.

A greater proportion of accidents occurs on Monday than on any other day of the week. Accidents are said to be due often to fatigue. As, after the day of rest on Sunday, workmen should be less fatigued than on other days, some other factor must be sought to explain this feature of the statistics. It has been suggested that the "blue Monday" accidents are really due to the fact that workmen take more liquor on Sunday, and thus become unnerved and more liable to accidents during the following twenty-four hours. There is, perhaps, something in this contention, says *The Journal of the American Medical Association*, though it has been disputed. In the Massachusetts Industrial Accident Board Reports, in which the official figures are given, there is scarcely more than one twentieth more accidents on Monday than on Tuesday, while Tuesday is not much above the average in the number of accidents reported for other days. Saturday, of course, shows a noteworthy reduction, because of the half holiday in some trades.

By far the larger number of accidents occur at about 10 A. M. and 3 P. M. This fact is confirmed by the reports of two State boards, Washington and Massachusetts. The tendency to speed up employment has been incriminated, as the predisposing condition for the occurrence of accidents. This desire comes over the workman when he is not yet fatigued, but has been employed for several hours. He starts the morning's work "cold," and as he warms to his work, the danger of mischance because of haste becomes greater. Just when the speeding up reaches a climax in the morning hours, most accidents happen. The same thing is true in the afternoon. Workmen feel sluggish after their lunch, but after an hour of work warm up again, and by about 3 o'clock they are doing their most rapid work, and are at the same time more subject to accidents.

With regard to accidents among children, however, there is no hour of maximum. Accidents occur at all times, and they are comparatively much more frequent among children than adults. The United States Bureau of Labor reported that "there is clear evidence of great liability to accident on the part of children. Though employed in the less hazardous work, their rates steadily exceed those of the older co-workers, even when in that group are included the occupations of relatively high liability." This was said with regard to the Southern cotton mills, but the same thing is true of practically all industries in which children are employed.

A Substitute for Platinum-Iridium Alloy

OWING to the scarcity and high price of iridium a recent inventor has proposed to substitute osmium in the well-known platinum-iridium alloy that has been widely used for many purposes. One part of osmium has been found to give the same hardness as two parts of iridium and the resulting alloy is ductile and is less affected by acids than platinum-iridium. Alloys with 10 per cent osmium are so hard as to be worked with difficulty, while a 2 per cent alloy is well suited for jewelry, as it is hard and tough, while alloys containing 6 to 10 per cent of osmium will serve all purposes that iridium alloys of from 15 to 25 per cent of iridium for contact points in electrical apparatus. In making these alloys metals of a very high degree of purity must be used. This alloy has been patented.

How to Increase Steam Production*

What Wider Knowledge and Better Design Has Accomplished

By H. Ross Callaway

IN the modern turbo-electric power station no general feature is perhaps so noticeable as the preponderance in size of the boiler room over the operating room. So successful have the turbine designers been in producing machines which, compared to reciprocating units of equal power, seem absurdly small, that the area of the engine room in big stations no longer is based upon the floor space necessary for the turbine-driven units themselves, but rather upon the area required for the condensing apparatus in the basement. And as the superiority of the turbine on a kilowatt per square foot basis has become more evident, the concentration of power in single units has increased until 20,000, 30,000 and even 40,000 horse-power machines have been built. So now in the power houses of the big public service companies we have the spectacle of enormous generating capacity confined within narrow physical limits such as formerly could have accommodated not more than one quarter of the output in the form of slow-speed reciprocating engines. But while this condensation has been going on in the operating room, what of the boiler house? What provision has been made for furnishing the enormous quantities of steam that such units require? Has an enforced increase in number of boilers more than offset the shrinkage of the engine room? The answer to these questions has already been stated. So great has been the increase in necessary boiler equipment, that the device of double decking was hit upon some years ago in order to economize on land investment. To-day almost all large stations situated on valuable ground (as a large proportion are) are provided with two stories of boilers. Yet even with this arrangement the area covered by the boiler house is approximately twice that of the engine room.

There is no indication that the ultimate limit of capacity of turbine units has been reached, in fact the rate of increase in power has been more rapid during the past two years than in the preceding decade. This has been made possible not only by the ability of the manufacturers to turn out units of greater dimensions but also by improvements in design tending to concentrate the actual application of power from the expanding steam into smaller volumes and with a marked increase in operating speeds. Whereas, a customary speed for 10,000-kilowatt units eight or ten years ago was 750 revolutions per minute, present practice recommends 1,500 to 2,000 revolutions per minute with a consequent increase in power output for a given size, or a decrease in the proportions of the connected generator. Yet with all these changes at the operating end of the steam cycle, very little has been done to increase the output of boiler units. The deadly doctrine of ten square feet of heating surface to a boiler horse-power still has a vast number of adherents despite the iconoclastic efforts of progressive engineers. That this proportion is correct for many installations is true, but because this is the case is surely no reason for its acceptance in designing large stations for maximum economy with an equipment of first-class water-tube boilers. The argument is advanced that a safe rating with an overload guarantee is justifiable, but it might be pointed out that turbo-generators are no longer sold on this basis—maximum capacity being now the general criterion. In the case of boilers, wide variations in capacity are of course common knowledge, due to different methods of setting, kind of firing, draft, furnace design, and other considerations which combine to make a standard horse-power rating almost impossible of achievement. Why not then abandon the antiquated horse-power bug-a-boo and buy boilers on the basis of square feet of heating surface? After all, that is the item which the designing engineer most needs to know. With such a standard, and the rate of evaporation determined by the conditions for each installation, the horse-power is easily determined—if anyone has curiosity on the subject.

If ten square feet is more than enough heating surface in up-to-date installations, let us see how it is possible to obtain an equal evaporation on one half or even one third that amount. The advantages of doing so are too obvious to require comment, yet the single statement that to halve the boiler equipment of a large turbine station designed on the ten square foot basis would reduce the land investment about one third is illuminating. In this discussion only water-tube boilers will be considered, as this type is almost universal in big station work, as modern plants are now organized.

There is an idea prevalent to a marked extent that "forcing" boilers is dangerous, that something will give if a 500 horse-power unit is made to produce 1,000 horse-power. To those possessed of this idea the actual performances at some large stations where "forcing" has been going on for several years should prove convincing. At these stations the two prime requisites of "overload" running, forced draft and automatic stokers, are installed. At first the idea of heavy overloads was put forward as a solution of a public lighting company's ever-present problem—that of handling sudden peaks, particularly thunderstorm peaks. When the demand for current increases suddenly at a rate of 3,000 to 5,000 kilowatts per minute, the means of meeting it must be most elastic; hence, the employment of overloads in the boilers in service. With the best types of stokers it is possible to run a banked boiler from a condition of thermodynamic equilibrium to 100 per cent above rating in five minutes. Such loads are for the most part of short duration, as other boilers may be put into active service within a short time to relieve the overloaded units. For some years, therefore, this use of the boiler's overload capacity was not extended, but a natural curiosity as to the effect of these over-ratings led to tests which proved conclusively that 200 per cent of rating might be made the standard capacity without injuring the units and with an economy in operation.

As a result some striking upheavals in power station practice are in process. A notable example is that of a large public service corporation's station built some ten years ago. Ninety-six 650 horse-power boilers were installed to take care of ten turbo-generating units with a total rated capacity of 91,000 kilowatts and a maximum capacity of about 115,000 kilowatts. Using the figure of 16 pounds of steam per kilowatt-hour and assuming an output of 100,000 kilowatts, the steam requirements would be 1,600,000 pounds per hour. The rated steam output per boiler, based on 34.5 pounds per horse-power from and at 212 degrees, amounts to 22,425 pounds per hour, or 19,500 pounds per hour from a feed water temperature of 180 degrees to steam at 175 pounds and 100 degrees superheat. Accordingly 82 boilers operating at rated capacity would have been able to handle the load, leaving 14 spare units. As the idea of running boilers at higher rates has spread, however, stokers of large capacity have replaced the fireman's shovel in this station, and bigger turbines have succeeded the original units until the ultimate generating capacity planned is nearly triple the original output *with no more boilers*. Two hundred per cent of rating is now common practice in this boiler house and 300 per cent is not considered unlikely in the near future. The use of stokers has lessened the operating charges and the maintenance has increased but slightly.

Even more startling is the experience at another station, designed five or six years ago, but erected only recently. Provision was made for the usual two tiers of boilers, but only the lower tier has been installed. The settings are unusually high, and it is expected to operate the boilers at 300 per cent of rating and not to install the top-floor boilers at all.

At another large plant they are remodeling the boiler equipment to establish an ultimate goal of 400 per cent of rating.

These instances might be multiplied, but perhaps those already cited will suffice to indicate the extent to which the idea of "forcing" is making its way among progressive operating men. More important than a further listing of individual examples is a review of the methods by which these results are accomplished.

It may be stated as an axiom that continuous loads much in excess of the ten square feet standard are impractical with hand firing. Not only is the work involved excessive, but smoke and low efficiency always result. Mechanical stokers are the first essential, then, for high rates of evaporation over considerable periods of time.

The second outstanding factor in "forcing" boilers is draft. If twice the rated evaporation is to be achieved, roughly twice as much coal will be burned, involving twice as much entering air which must be forced through thick fires and, as the boiler itself is not altered, through the passes at twice its former velocity. Under usual conditions this means forced draft to supplement the stack, and, indeed, many types of stokers are designed to be used only with air under pressure.

Economy of operation involves good boiler efficiency, and in the lust for large steam production this feature must not be lost sight of. Methods of feeding the coal and design of combustion chambers consonant with efficient burning of the fuel and rapid transfer of the heat are, therefore, essential. Smoke must be eliminated as far as possible.

Lastly, the design of the boiler itself should be such as to insure perfect circulation at a rapid rate of steam ebullition.

There are a number of automatic stokers on the market capable of giving uniformly excellent results at high ratings. Of these undoubtedly the best type is that in which the coal goes through a process of progressive heating; its volatile constituents are first driven off, to be consumed at a high temperature in the combustion chamber, the remaining solid framework (coke) growing gradually hotter as it is pushed into the fire zone, until its point of ignition is reached and it burns smokelessly in the white hot bed of the fire, and is at length reduced to ash at the dumping point. By this method, air, introduced cold into the coal, heats up in the same way as it progresses toward the fire proper and unites, first, with the volatile hydrocarbons, and then, at the surface of the fire, with the carbon of the solid fuel to give a normal combustion practically free from smoke.

The mechanical means by which this cycle is consummated is of far less importance than the proper succession of events in the cycle itself. Obviously, in hand firing this system of combustion is impossible, as the green coal is applied *beyond* the hot belt and, hence, the distilled volatile constituents pass off away from the fire bed instead of through it as in underfeeding. Then, too, the underfeed system materially reduces the cinder output, for not only is the heating gradual and, therefore, the formation of gases less violent, but also the cinders formed in this process must go through the fire belt, where a large proportion are consumed before reaching the boiler itself. With a stoker of this type the practical limit of combustion rate depends upon the maximum coal-feeding rate and the ability of the forced draft apparatus to supply sufficient air. As the rate of feeding is increased, the thickness of the fire as well as the volume of gases given off become greater, calling for more and more draft. The boiler itself is able to absorb as much heat as the fire can produce, so that the limit of overload capacity under present conditions hinges upon the ability of the stoker to furnish coal and the fans to furnish air, rather than upon the boiler itself.

It has been conclusively proven that a preponderant proportion of the steam-forming work of the boiler is done in the first pass of a multi-pass water-tube unit. Seventy per cent is a safe figure for this proportion in the case of a three-pass unit, and of this amount fully one half is accomplished by the lower three rows of tubes.

Even granting that these few tubes of the first pass are loaded to their limit in ordinary practice, it is evident that the output of gases could be doubled without affecting the rate of evaporation in the tubes beyond the first pass except in a small degree. The experiments of Prof. Nicholson have shown that the heat absorption capacity of boiler tubes may be increased astoundingly by increasing the gas velocities, and that is exactly what is done in "forcing." Quite recently the splendid researches of the Bureau of Mines in this country have confirmed Nicholson's results and pointed out unmistakably the importance of velocity as a factor in the heat transfer equation. In a different form the important work of Prof. Bone on surface combustion shows that the boiler will absorb easily as much heat as can be delivered to it within the limits of practicability, the only problem being that of getting the heat to the tubes.

In obtaining their remarkable heat transfers, both Nicholson and Bone had recourse to air pressures far in excess of those found in regular boiler practice, even in stations where "forcing" is the rule. Water-gage pressures of from 15 inches to 25 inches present practical difficulties in power station operation which, for the present at least, put their experimental results beyond reach, but in view of the strides already taken it scarcely seems chimerical to anticipate the ultimate surmounting of these obstacles.

For the present, four or five inches water gage, which is easily obtained with high-speed fans handling large volumes of air at a high velocity, suffices for the over-

* *The Engineering Magazine.*

loads under consideration. By balancing the draft under the grates with the induced draft from the stacks, a pressure is obtained in the combustion chamber which varies little from atmospheric—a condition that militates against leakage. In this way also it is possible to inspect the fire without danger of a sudden flare-out on the one hand or the inrush of a quantity of cold air on the other. For furnishing the large volumes of air necessary, the narrow bladed, centrifugal fan direct connected to either motor or steam turbine is admirably suited. By regulating the speed automatically through connection with a pressure indicator and at the same time synchronizing the fan and stoker mechanism, the entire boiler unit becomes self governing and fluctuations in load are taken care of almost instantly. Furthermore, the high rotative speed of the fan units results in an economy of space, always of the first importance in power station design.

The question may well be asked, What of the efficiency? It might seem that under conditions such as those described the gain in capacity might be offset by a marked drop in over-all efficiency. Tests, however, prove the contrary. In a long and careful investigation carried on over a period of many months in one of the largest and most efficient stations in this country, it was found that the efficiency curve rose gradually from rating to 50 per cent overload and then became practically flat up to 200 per cent of rating; beyond that point it dropped off, due principally to the inadequacy of the combustion chamber at higher loads. If, then, there is practically no loss in efficiency with settings designed for 100 per cent of rating, it is logical to expect even better results with combustion chambers and stokers designed for 200 per cent or 300 per cent of rating. As to the stokers, there is little difficulty in arranging for a more rapid feeding, the quicker rate being compensated for by a thicker fire. But as the rate of burning is increased, the problem of providing enough space in which the gases may be completely oxidized before reaching the cold tubes becomes acute. As it takes a certain appreciable time for the gases to burn, it is obvious that as their velocity is increased a point will be approached at which the products of combustion reach the tubes before the process of combustion has been completed. The cooling effect of the tubes stops the oxidation and, accordingly, partly unburned gases pass through the boiler with a consequent loss of efficiency and a production of smoke.

The patent remedy is to increase the size of the combustion chamber or, in other words, to give the gases time in which to be completely burned before reaching the tubes. Two methods present themselves: either the sectional area may be enlarged and the speed of the gases lowered in consequence; or the height of the chamber may be increased and the path of travel of the gases proportionally lengthened. Of the two the latter is that generally adopted, as the carrying out of the former involves structural difficulties of considerable moment. Head room is easily provided, however, and so the height of the boiler above the grates is steadily being increased. This method has the advantage over the Dutch oven and similar types of furnaces in that a larger proportion of the radiation of the fire is utilized. The construction is both simpler and cheaper and the maintenance charges are less.

That "forcing" does not result in short life to the boiler is due to the fact that at high loads the furnace temperature is but little higher than at rated capacity. A high rate of ebullition in the boiler has no deleterious effect; in fact, the quicker circulation confers a benefit through a scouring action which tends to discourage the formation of scale. Whatever strains are set up in a boiler, aside from those arising from pressure, result from expansion due to differences of temperature. As these strains are liberally provided for in the design a considerably higher furnace temperature would have little effect, and, as a matter of fact, the temperatures recorded are so little higher than those of former practice that their effects may be practically disregarded. As the steam pressure is not increased, the "forcing" process really affects the life of the boiler not at all. By the same reasoning, the fire brick will last about as long under "forcing" conditions as when the boiler operates at rating.

No trouble has been experienced with steam and water circulation in the best types of water tube boilers up to 100 per cent overload. At higher ratings, in certain types there is perhaps ground for doubt. In order to operate at 300 or 400 per cent of rating it is essential that the circulation of steam and water be unimpeded. The point of restriction, should there be any, would be at the front header, up which the steam passes from the tubes to the drum in boilers of the drum-and-header type. Constriction here would inevitably result in clogging the lower tubes with steam, which under the influence of the hot gases would become superheated, with a consequent rise of temperature at that point. There is no good reason, however, why the sectional area of the headers could not be increased if this proved to be the case. In boilers having single headers the full width of the tube-tank, this condition could scarcely arise, but where the designs call for individual headers for vertical rows of tubes, the question is at least worth considering.

In boilers with vertical or nearly vertical tubes (connecting steam and water drums) the possibility of choking the circulation is remote, and it is doubtful if any material change would be necessary even if the rate of operation called for a horse-power for two square feet of heating surface.

An additional aid to efficiency at high ratings is the increased heat transfer with the higher circulating speed. Nicholson demonstrated that not only is the transfer of heat units per square foot per degree difference of temperature per unit of time a function of the gas speeds, but also of the water speeds. With a rate of evaporation two, three, or four times as great as formerly, it is evident that the circulating speed of the water through the tube would be proportionally greater and that the rate of heat transfer would be increased materially.

The production of smoke and cinders under "forcing" such as that described, need cause little anxiety. With underfeeding and properly designed furnaces, smoke ceases to be a factor even with high-volatile bituminous coals. Cinders, the bane of many city plants, cannot be entirely eliminated in the furnace by the present methods of firing, although the production is materially lessened by underfeeding, as already mentioned. With high pressures under the grates a certain amount of cinders are inevitably blown from the fire bed through the boiler into the flues. In small installations, or in stations situated in sparsely inhabited sections, this is of small importance; in the case of large city stations, however, this is a serious feature.

To illustrate: assume a station running seventy-five 500 horse-power boilers at rating, a total of 37,500 boiler horse-power. With underfeed stokers and well designed furnaces an evaporation of 10 pounds of water per pound of coal may be expected, or 3 pounds of coal per boiler horse-power per hour. This would mean the burning of 112,500 pounds of coal per hour. A low figure for the amount of cinders given off under forced draft is 2 per cent of the coal fired. On this basis, such an installation would vomit upon the surrounding area 2,250 pounds of cinders per hour, or more than one short ton. At double rating, without considering the increase of percentage of cinders that would certainly result from the increased draft, the station would throw out 4,500 pounds per hour or 45,000 pounds for a ten-hour day—over 150 tons per week.

This problem has engaged the earnest attention of power-plant engineers for years, and very recently a solution has been found in the form of a practical cinder catcher which, after exhaustive tests, has proven completely successful. By this means over 95 per cent of the cinders are caught in the flue with only a very small loss of draft pressure. This invention has removed the last great economic obstacle to "forcing" boilers.

To sum up: The objections to higher ratings are either founded on lack of accurate knowledge or are capable of being overcome with little trouble. Proper design of furnace and stoker removes to a large degree the possibility of smoke formation. The amount of cinders formed is reduced by underfeeding and those formed are caught before reaching the stack. The efficiency drop at high ratings either does not exist or is too small for consideration. Sufficient draft is easily obtainable. Wear and tear on the boiler, despite opinion to the contrary, increases but very little as the capacity is increased, so that abnormal repair bills need not be anticipated.

The advantages are most marked: First cost may be halved—a smaller land investment with consequent lower interest is assured; costs of plant and building decrease in inverse proportion to the increase in ratings; maintenance, labor, and supplies are all lessened. In fact, there seems every reason to believe that the running of boilers at much higher ratings is the next logical forward step in power-plant operation.

A New Method of Surface Hardening

A VALUABLE application of the oxy-acetylene flame is its use for surface hardening steel parts that are required to withstand friction, and at the same time be very strong; and it is said to be especially applicable to parts of irregular shape. As an example, a crankshaft may be heat treated to obtain the greatest strength and toughness, and that by the application of the oxy-acetylene flame to the journals and quenching these parts may be readily surface hardened without affecting the quality of the body of the metal, as a thin surface layer may be raised to a tempering heat so rapidly that the temperature of the interior is not affected. The process has been patented in England.

The Density of Oxygen

IN the *Journal of Physical Chemistry*, A. O. F. Germann describes his method for determining the density of oxygen, and the apparatus he used. His determinations were made with oxygen prepared by heating potassium permanganate and purified by liquefaction and fractional distillation, and the value obtained for the weight of a normal liter of oxygen (at 0 degree and under a pressure of 760 millimeters of mercury in latitude 45 degrees at sea-level) was 1.42906 gramme. Taking into account the previous determinations, the author believes that the most probable value for the weight of a normal liter of oxygen, $L_n = 1.42905$.

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